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ERRATA.

Page 20, line 32, for " Le Pulley " read " Le Pelley "
,, 128, line 9, for " *typhoides* " read " *typhoideum* "
,, 130, 13 lines from end, for " *gerstaeckkeri* " read " *gerstaeckeri* "
,, 134, 7 lines from end, for " **bircarinatus** " read " **bicarinatus** "
,, 295, 12 lines from end, for " R. A. J. Lever " read " R. J. A. Lever "
,, 296, line 1, for " R. A. J. W. Lever " read " R. J. A. W. Lever "

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IMPERIAL INSTITUTE OF ENTOMOLOGY.

BULLETIN

OF

ENTOMOLOGICAL RESEARCH.

VOL. **31.** 1940.

ON THE NATURE AND ORIGIN OF THE DIAPAUSE IN *PLATYEDRA GOSSYPIELLA*, SAUND.

By F. A. SQUIRE.

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Although it may be convenient to distinguish them, hibernation, aestivation, and diapause are in reality different manifestations of the same phenomenon which we may call diapause. The symptoms of this condition are a marked depression of metabolism and quiescence; and the remote causes as suggested by observation are cold, heat, drought and (or) certain nutritional peculiarities such as richness or dryness of food. These factors may act singly or in combination, with different factors dominant in different cases.

Thus in the case of the Russian meadow moth, *Loxostege sticticalis*, L., Strelnikov[11] defines the factors inducing diapause as cold, drought, and richness of food. The latter is stressed by Steinberg & Kamensky[10] and appears to operate by binding some of the moisture. Dry food reduces the moisture content of the insect during the trophic phase and excessive heat increases the loss of moisture from both the food and the insect directly. Moreover Strelnikov's experiments show that cold and dryness of food are complementary factors.

It appears therefore that all the remote causes of diapause boil down in physiological terms to an unfavourable free water-balance.

In the case of the pink bollworm, *Platyedra gossypiella*, Saund., nutrition is the dominant factor causing this moisture deficiency; for as shown[8, 9] the larvae are subject more and more, as the crop advances, to food that is both drier and, as we shall see, richer in oil.

Normally the infestation starts on the flowers and is already high in the green-boll phase of the crop. At this stage the brunt of the attack is borne by bolls 30–36 days old, feeding is completed well before boll-split, and there is no diapause. As the ripe/green boll ratio rises, however, and the pest population increases, the infestation is forced on to older bolls with the result that larvae continue to feed after boll-split on drying food. In this way larvae penetrating three days before boll-split will ingest food of about 30 per cent. average moisture content, while the figure for those penetrating eleven days earlier is about 75 per cent.

At the same time there is an increase in the oil content of the seeds during maturation. According to Gallup[2] there is a period of intense oil formation just prior to boll-split. In two other papers, however, Gallup[3] and Caskey & Gallup[1] state that there is a critical period of oil formation between the 21st and 30th days. In view of this discrepancy, the oil content of seed of Sea Island cotton at different stages of maturation and with different manurial treatments was investigated in St. Vincent, and the results are given below.

The method of ether extraction employed both here and later to assess the fat content of larvae is that recommended by the American Association of Agricultural Chemists.* The seeds were oven-dried at 100°C. for 2 hours, finely ground in a coffee mill, and treated with ether in a soxhlet for 4 hours. This work was done in collaboration with Mr. C. C. Seale, Assistant Agricultural Superintendent, St. Vincent. The samples were taken with the kind permission of Mr. C. K. Robinson, Agricultural Superintendent, St. Vincent, from a combined varietal manurial experiment laid down by him.

TABLE I.

Sea Island Cotton, Strain V.135.

Stages of Maturation.

Manurial treatment	Age of seed in days.					
	27	34	39	47	52	56
	Percentage oil content of seed.					
V	Samples from all treatments lumped.	Samples from all treatments lumped.	22·38	24·86	26·64	27·11
VN			21·12	22·38	27·33	27·13
VP			21·95	23·57	28·17	27·81
VK			20·95	23·46	28·11	28·53
VNP	Sample A	Sample A	21·91	23·27	26·17	26·18
VNK	4·54	9·65	21·03	24·16	25·53	27·33
VPK	Sample B	Sample B	20·64	23·20	27·32	26·78
VNPK	4·55	9·82	19·23	23·85	25·66	25·79
Averages ...	4·55	9·73	21·15	23·59	26·86	27·08

V = Sea Island Cotton, Strain V.135.
N = 3 cwt. of sulphate of ammonia per acre.
P = 3 ,, ,, superphosphate per acre.
K = 2 ,, ,, sulphate of potash per acre.

---

* Official and Tentative Methods, 4th Edition. Association of Agricultural Chemists.

TABLE II.

Sea Island Cotton, Strain M.S.I.

Stages of Maturation.

	Age of seeds in days.			
	31	37	44	56
	Percentage oil content of seed.			
Samples A	7·22	18·28	24·30	28·34
,, B	6·80	18·14	24·95	26·76
Means	7·01	18·21	24·61	27·55

The increase in the oil content of cotton seed at different stages of maturation as shown by these figures is graphically represented by Fig. 1.

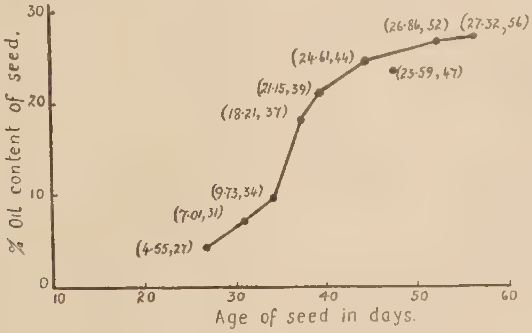

Fig. 1. Oil content (percentage of oven dry weight) of cotton seed at different stages of maturation.

From Fig. 1 the percentage oil content of the total food ingested by larvae penetrating at different boll ages may be calculated :—

TABLE III.

Age of boll at penetration	Percentage oil content of total food ingested.
30	15·6
35	21·8
40	25·2
45	26·6
50	27·3

These nutritional differences give rise to corresponding chemical differences in the composition of the larva. Thus resting larvae often have a moisture content as much as 10 per cent. lower than that in normal larvae. In this connexion it is interesting to note that Bodine, cited by Uvarov[12], has found that the moisture content of hibernating grasshoppers is almost 10 per cent. lower than that of normal adults.

The fat content of resting larvae is considerably higher. Analyses made by Dr. T. G. Mason, F.R.S., of the Empire Cotton Growing Corporation, of material submitted by the present writer gave the following results :—

TABLE IV.

Percentage of oven dry weight.

	Samples		Mean
	A	B	
Diapause	47·7	43·7	45·7
Normal	32·8	36·2	34·5

Further analyses made by the present writer of fresher material gave even greater differences. At the same time a sample of the same lot of resting larvae was kept in moist cottonwool for 48 hours and analysed. These results, together with specific gravity readings taken with a Zeiss refractometer at 28°C., are given below :—

TABLE V.

Percentage of oven dry weight.

	Samples			Mean	S.G.
	A	B	C		
Diapause	40·5	40·5	46·2	42·~~7~~4	1·466
Normal	26·8	25·5	30·5	27·6	1·466
Diapause larvae kept in moist cottonwool for 48 hours	38·3	37·2	—	37·75	1·467

S.G. of cotton seed oil 1·470.

These larvae had been in diapause for about six months. It will thus be seen that the ether extract of diapausing larvae may be about 15 per cent. higher than that of normal larvae. The application of moisture to resting larvae, as has been shown[8, 9] terminates diapause and causes pupation. From the figures above it is clear that the physiological effect of this step is to reduce the fat content (probably by facilitating hydrolysis) of such treated diapausing larvae, thus bringing them into line with normal larvae. Here it may be noted that Kozhantshikov[6] found the fat content of diapausing larvae of *Pyrausta nubilalis* to be as high as 50 per cent., at least 10 per cent. higher than that of normal larvae. In the case of the pink bollworm the fat and potential energy ingested is evidently in excess of its energy requirements, particularly in the case of late penetrating larvae, and is stored in tissues. It will be seen that the S.G. of the fat is close to that of the oil ingested. Both cotton seed oil and the stored fat are liquid at 28°C.

Another difference lies in the rate of metabolism of which the respiration may be taken as an index. Bodine, cited by Uvarov [12], states that the rate of respiration is 8–10 times lower in hibernating grasshoppers than in normal ones ; and Squire[7] has shown that the rate of respiration of diapausing pupae of *Papilio anchisiades* drops almost to zero.

In the light of these facts concerning the nature of diapause it may be possible to form an idea of the manner in which the larval diapause of *Platyedra gossypiella* originated. But first it will be necessary to consider the habits of the cotton plant.

According to Hutchinson[4] " All the wild spp. of *Gossypium* and the more primitive forms of cultivated species are perennial " and " all the early literature on cotton in India speaks of the cultivation of perennials and it is safe to assume that in the 10th century annual cottons were practically unknown in India except possibly in the hill tracts of Bengal and Assam." Again Hutchinson and Ghose[5] state " the recent evolutionary trend throughout the cultivated sections of the genus appears to have been from the perennial predominantly monopodial habit to small early flowering, early maturing, annual, predominantly sympodial bushes."

The specialized bionomics of *P. gossypiella* indicates that its association with cotton is an ancient one, and it may therefore be concluded that the pink bollworm evolved on a perennial cotton. For this reason it is interesting to observe the habits of existing wild cottons.

Two such species, *G. religiosum* and *G. purpurascens*, occur in the West Indies. In the wetter islands and especially in fringing thickets these species flower and fruit perennially, while in those islands which have a more or less defined dry season there is a period of semi-dormancy, the duration of which depends on the length and severity of the dry season.

It is conceivable that the primitive pink bollworm was associated with perennially fruiting cotton in certain restricted localities favoured with a constant supply of soil moisture and that it lacked a diapause. Naturally there would be a tendency for it to spread and adapt itself step by step to cotton with longer and longer periods of dormancy. And this in the absence of diapause and in ordinary circumstances would merely result, in the initial stages, in retardation and eventually death as the available food supply became drier and drier. But the ability to utilize the oil in the seed in the formation of reserve fat doubtless helped the insect to bridge this unfavourable period ; and so this ability became of selective value and the insect gradually acquired a diapause commensurate, under natural conditions, with the period of dormancy imposed on the cotton host by its environment. In sheltered, artificial situations the diapause may, of course, be much longer.

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THE AFRICAN SPECIES OF *METAPHYCUS*, MERCET.*

By Harold Compere.

Assistant Entomologist, University of California Citrus Experiment Station, Riverside, California.

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Metaphycus subflavus, Timberlake	33

Genus **Metaphycus,** Mercet.

Metaphycus, Mercet (subgenus), Fauna Iberica, Fam. Encirtidos. Mus. Nac. Cien. Nat., Madrid, 1921, p. 197.

Metaphycus, Mercet (genus), Eos, 1 (1), 1925, pp. 7–31.

Twenty-three species of *Metaphycus* from Africa are recognized in this paper, and of these, seventeen are described as new. The holotypes and allotypes of all new species are to be deposited in the British Museum and paratypes in the United States National Museum.

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* Paper No. 396, University of California Citrus Experiment Station, Riverside, California.

R. G. Mercet erected the genus *Metaphycus* for species with four-jointed maxillary palpi, three-jointed labial palpi, and with distinct lines on the mesoscutum indicative of parapsidal furrows. He erected the genus *Euaphycus* for species with two- or three-jointed maxillary palpi, two-jointed labial palpi, and with less distinct parapsidal lines on the mesoscutum. Another character that was used by Mercet to distinguish the species of the two groups was the comparative thickness of the integument. The species of the first group, *Metaphycus*, are larger with thicker integument, so that the head and thorax usually retain their shape after drying.

Previously, I followed the lead of Mercet and classified species with two- or three-jointed maxillary palpi and two-jointed labial palpi under *Euaphycus*. In this paper *Euaphycus* is not used, and species with two- or three-jointed maxillary palpi and two-jointed labial palpi are classified under *Metaphycus*. Since there is a difference of opinion as to whether or not some of the species should be classified under *Euaphycus*, this genus has not been formally placed in synonomy. Anyone wishing to use the name *Euaphycus* for the species described in this paper which are in agreement with Mercet's concepts, can easily do so by the use of characters given in the key. Reasons for not using *Euaphycus* follow.

It seems doubtful whether subdivisions based on the number of joints in the palpi represent natural groups of species. When subdivided in this way, a great many closely related species are brought together. However, there are some species, so much alike that they are difficult to separate by other characters, which fall into different groups when subdivided on the basis of the number of joints in the palpi. A good example is provided by *flavus* (Howard), *luteolus* (Timberlake), and *stramineus*, sp. n. In *flavus* the maxillary palpi are three-jointed and the labial palpi, two-jointed ; in *luteolus* both maxillary and labial palpi are three-jointed ; while in *stramineus* both maxillary and labial palpi are two-jointed. These three species can scarcely be distinguished from one another with assurance except by the number of joints in the palpi. Only one species was known to Mercet in which both the maxillary and labial palpi were three-jointed, namely, *insidiosus*, Mercet. This species Mercet considered to be anomalous and referred it to *Metaphycus*. In this paper six new species are described which have both maxillary and labial palpi three-jointed. If *Euaphycus* were used as a generic name for species with two- or three-jointed maxillary palpi and two-jointed labial palpi, it would be necessary, for uniformity, to erect at least one new genus to provide for the species having both maxillary and labial palpi three-jointed.

Most of the descriptions published prior to the appearance of Mercet's work on the classification of *Metaphycus*, in 1921, make no mention of the number of joints in the palpi. Because of this, it is not now possible to assign many of the older species to new groups on the basis of the number of joints in the palpi, unless the original specimens are re-examined or additional authentically identified specimens are obtained. Some of the types have been lost and others damaged. At this time it seems inconvenient and impracticable to erect new genera or to use *Euaphycus* as a generic name.

The characters used by Mercet to distinguish *Euaphycus* from *Metaphycus*, other than the number of joints in the palpi, are far less reliable. In all the species which I have seen, regardless of the number of joints in the palpi, there are on the sides of the mesoscutum imperfectly developed lines converging toward the meson. In *Metaphycus zebratus*, Mercet, the genotype, this character is very strongly developed, and in tag-mounted specimens it appears as blackish lines which meet posteriorly on the meson. In the smaller, less rigid species, with a reduced number of joints in the palpi, this character is not evident in tag-mounted specimens but is visible in balsam-mounted specimens as short lines of thinner or less opaque integument on the sides of the mesoscutum.

Key to the African Species of Metaphycus, *Females and Males.**

1. Maxillary and labial palpi either two- or three-jointed..............................14
Maxillary palpi four-jointed and labial palpi three-jointed...........................2

2. Males...10
Females 3

3. Ovipositor concealed or shortly exserted ; if exserted, the protruding portion of sheaths less than one-third the length of abdomen ; the sheaths not much, if any, longer than the spur of middle tibiae......................................5
Ovipositor strongly exserted ; the protruding portion of sheaths as long as one-third or one-half the length of abdomen ; the sheaths plainly much longer than the length of the spur of middle tibiae................................4

4. Ovipositor exserted one-half the length of abdomen ; the sheaths slightly more than three times as long as the spur of middle tibiae. Frontovertex slightly more than twice as long as wide. Ocelli in a strongly acute triangle. Scape twice as long as wide (Uganda)..........................1. *ferrierei*, sp. n.
Ovipositor exserted one-third the length of abdomen ; the sheaths slightly more than twice as long as the spur of middle tibiae. Frontovertex about one and one-half times as long as wide. Ocelli in an equilateral triangle. Scape three times as long as wide (Eritrea)..............2. *albiventris*, sp. n.

5. Tibiae, especially those of middle legs, with dark spots or bands.................7
Tibiae without dark spots or bands...6

6. Flagellum uniformly blackish or brownish yellow. Scape slightly less than three times as long as wide ; all funicle joints slightly longer than wide, and the sixth not much wider than the first ; pedicel subequal in length to the first funicle joint. Frontovertex slightly less than twice as long as wide (Natal)..3. *fuscicornis*, Compere
Funicle joints yellowish with the club blackish in distinct contrast. Scape more than three times as long as wide ; all funicle joints gradually increasing in width distad, the first not much longer than wide, and the sixth almost twice as wide as long ; pedicel slightly longer than the first funicle joint. Frontovertex about one and one-half times as long as wide (Natal).........
4. *natalensis*, Compere

7. Scape wide and approximately three times as long as wide........................9
Scape narrow and plainly more than three times as long as wide..................8

8. Cheeks not marked with blackish. Frontovertex about twice as long as wide. Sixth funicle joint about one and one-half times as wide as long (Natal)......
5. *lineascapus*, sp. n.
Cheeks marked with blackish. Frontovertex two and one-half times as long as wide. Sixth funicle joint about as wide as long (Natal, Kenya Colony)......
6. *hemilecanii*, sp. n.

9. Frontovertex very narrow, fully three times as long as wide. Ocelli in a strongly acute triangle. Eyes distinctly hairy (Kenya colony)......7. *lepelleyi*, sp. n.
Frontovertex twice as long as wide. Ocellar triangle variable, either acute or equilateral. Eyes very minutely hairy, appearing bare under ordinary magnifications (South Africa, Eritrea, New South Wales, Queensland, California)...8. *lounsburyi* (Howard)

---

* The following species are not represented by ♂♂ and in this sex do not appear in the key : *ferrierei*, sp. n. ; *albiventris*, sp. n. ; *lepelleyi*, sp. n. ; *mauritanicus*, sp. n. ; *inviscus*, sp. n. ; and *limuruensis*, sp. n. *Metaphycus subflavus*, Timberlake, does not appear in the key in either sex.

10. Scape ranging from about three to four times as long as wide....................12

Scape very narrow, ranging from about six to seven times as long as wide. Tibiae with conspicuous black spots or bands; femora of middle legs slightly marked with blackish on ventral aspect near apex. Frontovertex almost twice as long as wide, or longer. Ocelli in a strongly acute triangle. Pedicel about as long as the first two funicle joints united. Mesoscutar-axillar and scutellar-axillar sutures blackish..11

11. Cheeks whitish. Frontovertex slightly less than twice as long as wide (9 : 5) (Natal)..5. *lineascapus*, sp. n.

Cheeks marked with blackish. Frontovertex slightly more than twice as long as wide (9 : 4) (Natal, Kenya Colony)......................6. *hemilecanii*, sp. n.

12. Flagellum uniformly yellowish or brownish. Legs immaculate or with the middle tibiae faintly spotted with brown. Frontovertex plainly less than twice as long as wide..13

First four funicle joints and club blackish or largely so; fifth and sixth funicle joints yellowish. Tibiae with distinct dark spots or bands. Frontovertex almost twice as long as wide (South Africa, Eritrea, New South Wales, Queensland, California)....................................8. *lounsburyi* (Howard)

13. Legs immaculate. Frontovertex not much longer than wide (9 : 7). Ocelli in slightly less than a right triangle. Scape slightly more than three times as long as wide (13 : 4); distal funicle joints strongly transverse, and the sixth almost twice as wide as long; club short, slightly more than one and one-half times as long as wide, as long as the preceding three funicle joints united; pedicel about one and one-half times as long as wide, as long as the first two joints of the funicle united (Natal)...........4. *natalensis*, Compere

Tibiae of middle legs very faintly spotted with brown. Frontovertex less than twice as long as wide (9 : 5½). Ocelli in an equilateral triangle. Scape four times as long as wide; distal funicle joints not much, if any, wider than long; club twice as long as wide and not quite so long as the preceding three funicle joints united; pedicel one and one-half times as long as wide and plainly shorter than the first two joints of the funicle united (Natal) .... 3. *fuscicornis*, Compere

14. Maxillary and labial palpi both two-jointed...23

Maxillary and labial palpi both three-jointed...15

15. Males 21

Females 16

16. Cheeks distinctly marked with blackish. Tibiae of middle and hind legs distinctly spotted or banded; femora of middle legs sometimes marked with blackish or brown on ventral aspect near apex..................................18

Cheeks yellowish or white without blackish markings. Legs immaculate, or the middle or middle and hind tibiae faintly spotted with brownish..............17

17. Scape at least four times as long as wide and white except for a small, elongated blackish mark on outer aspect toward the apex; radical joint white; pedicel entirely white or nearly so. Eyes plainly hairy (Morocco)........... 9. *mauritanicus*, sp. n.

Scape ranging near two and one-half times as long as wide and largely black, only the ends and dorsal margin more or less white; radical joint and basal half of pedicel blackish. Eyes almost imperceptibly hairy (Cape Province, Kenya Colony, Eritrea, California)..........................10. *stanleyi*, sp. n.*

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* The complete description of *Metaphycus stanleyi*, sp. n., will appear in the University of California Publications in Entomology.

18. Scape two and one-half to three times as long as wide. Ovipositor, as seen through the integument in cleared specimens, longer than the tibiae of middle legs........20

Scape slightly more than twice as long as wide. Ovipositor, as seen through the integument in cleared specimens, shorter than the tibiae of the middle legs...19*

19. Scape slightly more than three times as long as wide (20 : 6). Speculum interrupted by three rows of hairs; the basal, cut-off portion plainly less than its own length apart (Cape Province)........11. *inviscus*, sp. n.

Scape about two and one-half times as long as wide (23 : 9). Speculum interrupted by five or six rows of hairs; the basal, cut-off portion small, plainly more than its own length apart (Kenya Colony) ....12. *limuruensis*, sp. n.

20. Frontovertex two and one-half times as long as wide. Club almost twice as long as wide (17 : 9), subovate, and strongly rounded at the apex. Speculum interrupted by five rows of hairs; the basal, cut-off portion separated by more than its own length. Tibiae of hind legs strongly marked with blackish. Notum of thorax and tergum of abdomen with compound sculpture, the reticulated lines enclosing secondary aciculations (Natal)...13. *obtusus*, sp. n.

Frontovertex slightly more than twice as long as wide. Club about one and one-half times as long as wide (19 : 12), semirectangular, the dorsal and ventral margins nearly parallel, and the apical margin slightly rounded. Speculum interrupted by three rows of hairs; the basal, cut-off portion large, separated by plainly less than its own length. Tibiae of hind legs faintly and obscurely marked with brownish. Notum of thorax and tergum of abdomen with simple sculpture, the reticulated lines not enclosing secondary aciculations (Natal and, questionably, Uganda)........14. *truncatus*, sp. n.

21. Cheeks marked with blackish. Tibiae with conspicuous dark markings......22

Cheeks pale yellowish white or colourless. Tibiae without conspicuous dark markings. Mesoscutum, axillae, and scutellum yellow (Cape Province, Eritrea, Kenya Colony, California)........10. *stanleyi*, sp. n.

22. Scape about three times as long as wide with the ends and dorsal margin broadly yellowish white. Speculum interrupted by three or four rows of hairs. Notum of thorax and tergum of abdomen with compound sculpture, the reticulated lines enclosing secondary aciculations (Natal) .... 13. *obtusus*, sp. n.

Scape almost twice as long as wide (11 : 5) and black except narrowly at ends. Speculum interrupted by two rows of hairs. Notum of thorax and tergum of abdomen with simple sculpture, the reticulated lines not enclosing secondary aciculations (Natal and, questionably, Uganda)........14. *truncatus*, sp. n.

23. Males 31

Females........24

24. Scape ranging from about two and one-half to four times as long as wide......25

Scape five times as long as wide, neither compressed nor expanded below. The wings with or without a small integumentary infuscation beneath the marginal vein. Tibiae of middle legs faintly spotted or suffused with brownish (Cape Province, Natal)........15. *aspidiotinorum*, sp. n.

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* *Metaphycus insidiosus*, Mercet, runs to couplet 19 in the key. According to Mercet's description and figure, in *M. insidiosus* the scape is two and one-half times as long as wide, and the speculum is interrupted by three rows of hairs. The new species, *M. inviscus*, *M. limuruensis*, *M. obtusus*, and *M. truncatus*, are very similar to one another and to *M. insidiosus*, Mercet. If the diagnostic characters used in the key prove to be variable, some of these species may eventually be synonymized.

25. Scape ranging from about two and one-half to three times as long as wide...27
Scape a trifle less than four times as long as wide..................................26

26. Legs immaculate. General colour pale lemon-yellow, with the sides of mesoscutum, axillae, and scutellum faintly dusky; collar of pronotum solidly marked with brown from the corners of the collar to near the insertion of the neck, without the usual isolated dots on the corners. Scape largely pale yellowish white with an elongated, obliquely transverse brown spot on the outer aspect of apical half (Cape Province)...............16. *stramineus*, sp. n.
Legs spotted with brown on the middle and hind tibiae. General colour yellow with the pronotum, anterior margin of mesoscutum, metanotum, propodeum, and basal tergites brown. Scape largely black with the ends and dorsal margin white (Eritrea)..17. *praevidans* (Silvestri)

27. Mesoscutum and axillae separated by blackish sutures; the sides of the mesoscutum, axillae, and scutellum largely blackish. In the general effect, the mesonotal sclerites appear as though framed in blackish........................30
Mesonotal sclerites not appearing as though framed in blackish, although some blackish or brown may be present, especially anteriorly on the mesoscutum...28

28. Legs with the middle tibiae spotted or with a faint brown suffusion near base...29
Legs immaculate; the middle tibiae never with any indications of brown or dusky near the basal ends (Cape Province, California)...18. *helvolus* (Compere)

29.* (Eritrea)..19. *aethiopicus*, sp. n.
(Natal)..20. *confusus*, sp. n.

30. Frontovertex about one and one-half times as long as wide. Posterior ocelli about twice their own diameter apart. Collar of pronotum with isolated blackish spots on either corner (Natal)..........................21. *cerinus*, sp. n.
Frontovertex about twice as long as wide. Posterior ocelli scarcely more than once their own diameter apart. Pronotum with blackish extending from the corners of the collar to near the insertion of the neck on the anterior concealed aspect (Natal)..22. *africanus*, sp. n.

31. Scape usually at least three times as long as wide and not distinctly compressed or expanded ventrally...32
Scape two and one-half times as long as wide, distinctly compressed and expanded ventrally, and largely blackish. Mesonotal sclerites yellow with blackish on the margins (Natal)..22. *africanus*, sp. n.

32. Cheeks yellowish or whitish...33
Cheeks largely brownish or blackish. Fore wings with or without a small integumentary infuscation beneath the marginal vein (Cape Province, Natal)...
15. *aspidiotinorum*, sp. n.

33. Tibiae of middle legs without brown spots..35
Tibiae of middle legs with brown or blackish spots..................................34

34. Fore wings with a fuliginous cloud beneath the stigmal vein (Eritrea)...........
17. *praevidans* (Silvestri)
Fore wings hyaline beneath the stigmal vein (Eritrea)......19. *aethiopicus*, sp. n.

35. Flagellum not conspicuously hairy, the hairs fine and colourless or nearly so...37
Flagellum conspicuously hairy at ordinary magnifications, the hairs comparatively coarse and dark 36

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* What are supposedly two distinct species run to couplet 29. In the ♀ sex no characters can be discovered by which to separate them. In the ♂ sex, however, the two forms appear to be distinct. In the absence of the ♂♂, it may not be possible to distinguish between these two species.

36. Mesonotal sclerites brownish. Sixth funicle joint plainly longer than wide, and the fifth about as long as wide (Cape Province).........16. *stramineus*, sp. n.

Mesonotal sclerites largely yellow with blackish sides, the general effect as if framed in blackish. Funicle joints, except the first, plainly wider than long (Natal)...21. *cerinus*, sp. n.

37. Sixth funicle joint longer than wide (Natal)......................20. *confusus*, sp. n.

Sixth funicle joint wider than long (Cape Province, California)..................... 18. *helvolus* (Compere)

1. Metaphycus ferrierei, sp. n. (fig. 1).

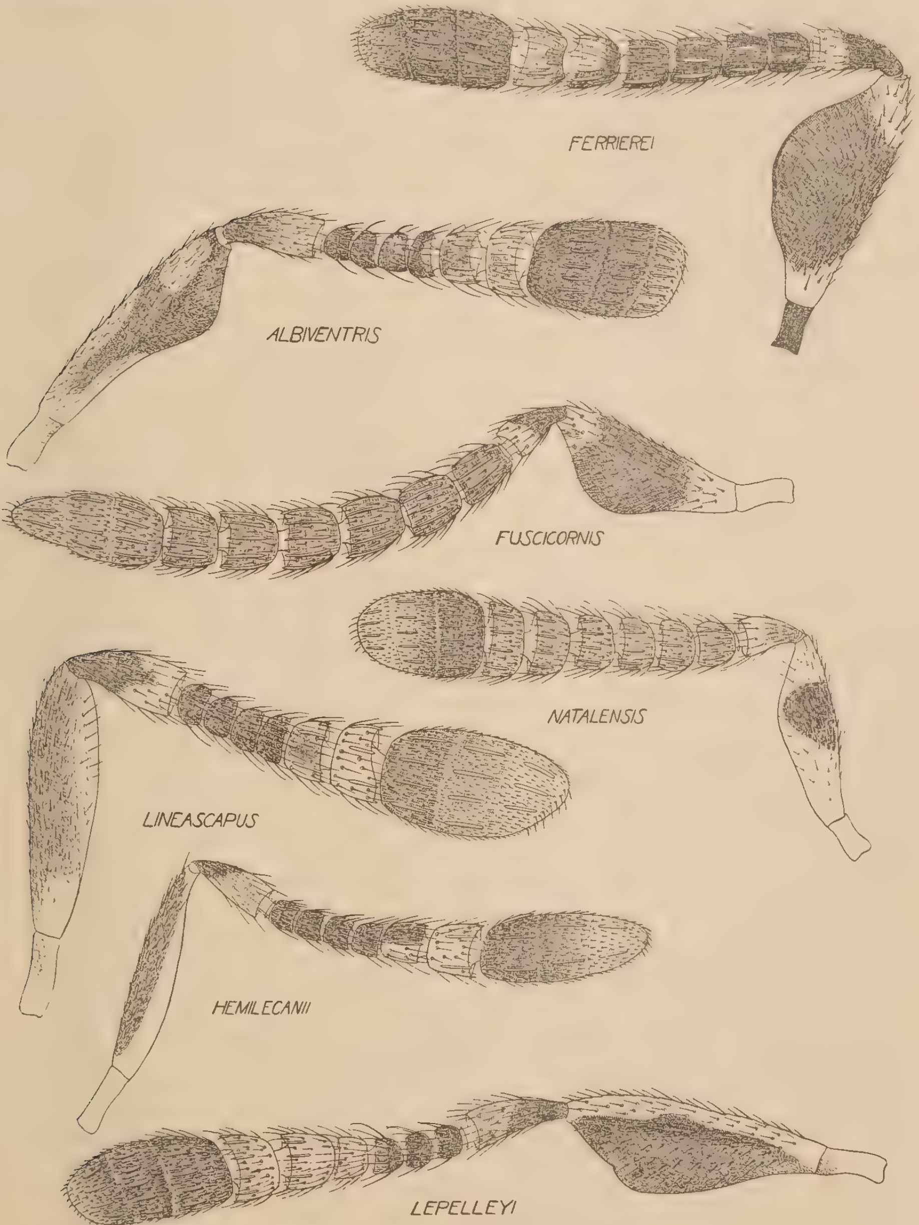
FERRIEREI
ALBIVENTRIS
FUSCICORNIS
NATALENSIS
LINEASCAPUS
HEMILECANII
LEPELLEYI

Fig. 1. *Metaphycus* spp., ♀♀; antennae.

This is a large, distinctive species easily distinguished from previously described species by the ovipositor, which protudes fully one-half the length of the abdomen.

♀. Frontovertex slightly more than twice as long as wide (9 : 4), punctate reticulate. Ocelli in a strongly acute triangle ; anterior ocellus slightly more than its own diameter from the orbits ; posterior ocelli about once their own diameter apart, about one and one-half times their diameter from the occipital margin, and one-half their diameter from the orbits. Cheeks much shorter than the transverse diameter of the eyes. Cheeks and the face between the antennal sockets with numerous, long white hairs. Eyes with moderate-sized white hairs. Scape expanded, slightly less than twice as long as wide (17 : 9) ; pedicel not much more than twice as long as wide ; first funicle joint as long as wide and slightly less than one-half as long as the pedicel ; funicle joints slightly increasing in width distad, so that the sixth is about one and one-third times as wide as long and scarcely longer than the first ; club one and one-half times as long as wide, more than twice as wide as the sixth funicle joint, bluntly rounded at apex, and as long as the preceding three funicle joints united. Scutellum as long as wide and as long as the mesoscutum, the latter with conspicuous black lines extending from the sides and almost meeting on the meson. *M. zebratus*, Mercet, is the only other described species with the parapsidal lines so distinct. Abdomen longer than usual, inclusive of the exserted ovipositor, and slightly longer than the head and thorax combined, as seen in tag mounts after shrinkage ; ovipositor sheaths coarse, one-half as long as the abdomen.

Fore wings more than twice as long as wide (22 : 9) ; marginal vein wider than long. Speculum interrupted by two or three rows of hairs ; the basal, cut-off portion separated by about its own length and not continuous with the posterior marginal bare streak.

Mandibles with three nearly equal teeth. Scrobes semicircular above.

Frontovertex yellow ; upper portion of face yellow, fading to white near the antennal sockets and with the oral margin narrowly blackish ; cheeks pale yellow to white with a large, sharply defined black blotch near the mouth. Scape black with the base and apex white ; radical joint, basal two-thirds of pedicel, first four funicle joints, and club black ; fifth and sixth funicle joints partly white, the ventral aspects suffused with blackish. Occiput largely black with the upper margins pale yellowish white. Collar of pronotum white with a faint dot on either corner. Mesoscutum, axillae, and scutellum largely yellowish with some admixture of pale brownish ; the sutures and anterior portions of the sclerites with some blackish, finely punctate reticulate, and covered with white, appressed hairs. Sides of pronotum, base of tegulae, prepectus, mesopleura, sides of propodeum, and sternum of thorax white and in places translucent. Metanotum, propodeum mesad of spiracles, and most of tergum of the abdomen blackish to dark brown ; basal corners on tergum of abdomen, lateral margins posterior to vibrissal plates, and the venter whitish. Ovipositor sheaths blackish. Coxae white ; femora largely white with some brownish suffusions ; front and middle tibiae with two pairs of brown dots, and hind tibiae brownish on dorsal aspect.

Length, inclusive of ovipositor, 1·9 mm. ; ovipositor exserted 0·35 mm.

Described from 1♀, holotype, from *Ceroplastes* sp. on citrus, Kampala, Uganda, 18.x.1935. This specimen was received several years ago for identification. It was submitted by Dr. Norman S. Noble, Department of Agriculture, New South Wales, and bears his data : " Expt. B 11. Species No. 17."

After the above description was made, the specimen was boiled in 10 per cent. KOH until clear, then passed through glacial acetic acid and oil of cloves and mounted on a slide in balsam. An untreated wing and antenna are on a separate slide. Generally, specimens such as this holotype are of more value for descriptive purposes if not mounted on a slide in balsam but mounted, instead, on a card point. In order to place this species, as well as several others, in the key, it was necessary to clear and mount the holotypes in balsam, so that the number of joints in the palpi could be ascertained.

2. **Metaphycus albiventris,** sp. n. (fig. 1).

This species, like the preceding, *M. ferrierei*, can be distinguished by the strongly exserted ovipositor, although in this species the ovipositor is not of such unusual length.

♀. Frontovertex slightly less than one and one-half times as long as wide (11 : 8). Ocelli in an equilateral triangle ; anterior ocellus almost twice its own diameter from the orbits ; posterior ocelli about once their own diameter from the occipital margin and slightly less than this distance from the orbits. Head, in dorsal view, strongly concave on anterior margin between orbits. Scrobes shallow, triangularly convergent, and ascending high between the orbits with the triangular raised area between the scrobes just visible in dorsal view when the head is vertical. Eyes very faintly hairy. Scape expanded distad of the middle and about three times as long as wide (34 : 11) ; pedicel slightly more than twice as long as wide (13 : 6) and almost as long as the first four funicle joints ; first funicle joint slightly wider than long (5 : 4) ; funicle joints gradually increasing in width from the first to the fourth, the latter almost twice as wide as long (7 : 4) and scarcely any longer than the first ; sixth funicle joint one and two-thirds times as wide as long and one and one-half times as long as the first ; club short, one and one-third times as long as wide, suboval, and as long as the preceding four funicle joints united. Scutellum as long as wide and slightly longer than the mesoscutum, the latter with parapsidal sutures indicated on the sides by short lines of thinner or less opaque integument and not at all blackish as in the preceding species. Abdomen short, ovate ; ovipositor exserted almost one-third the length (7 : 23).

Fore wings very finely and densely hairy. Speculum interrupted by two or three rows of hairs ; the basal, cut-off portion small, separated by scarcely more than its own length, and widely separated from the posterior marginal bare streak.

Frontovertex pale lemon-yellow ; face and cheeks white to pale yellow ; centre of occiput blackish. Scape with the inner aspect white except for the ventral expansion distad of the middle, which is black ; outer aspect more extensively black ; the basal half largely white with a large white spot on dorsal part near apex ; apical portion of radical and basal portion of pedicel blackish ; first two or three funicle joints completely black ; succeeding funicle joints with progressively increasing admixtures of yellowish ; club, except the apical margin, black. Collar of pronotum white with a dark dot on either corner ; concealed part blackish. Disks of mesoscutum, axillae, and scutellum yellow ; anterior portion of mesoscutum, slides, and sutures of mesonotal sclerites black ; metanotum and propodeum mesad of spiracles black ; tergum of abdomen, except on sides and at apex, blackish to dark brown ; ovipositor sheaths blackish to brown ; pleura and sternum of thorax and venter of abdomen pallid white. Legs white with conspicuous dark markings ; all tibiae more or less blackish at ends and with two pairs of large suffused spots or imperfect bands ; middle and hind femora with dark suffused spots on ventral aspects.

Length, 1·6 mm. ; ovipositor sheaths 0·28 mm.

Described from 1 ♀, holotype, reared from an unidentified Coccid, probably a *Ceroplastes* sp., infesting *Olea chrysophylla*, Nefasit, Eritrea, 10.iv.1930, H. Compere.

3. **Metaphycus fuscicornis,** Compere (fig. 1).

Metaphycus fuscicornis, Compere, Univ. Calif. Publ. Entom. **4** (8), 1928, pp. 220–21.

This distinctive species was reared from *Inglisia* sp. on cotton plants by E. W. Rust, Durban, Natal, 1926.

4. Metaphycus natalensis, Compere (fig. 1).

Metaphycus natalensis, Compere, Univ. Calif. Publ. Entom. **4** (9), 1928, pp. 291–92.

A distinctive species reared from *Saissetia oleae* (Bern.) and *Filippia carissae*, Brain, by E. W. Rust, Durban, Natal, 1925–26.

5. Metaphycus lineascapus, sp. n. (fig. 1).

This and the following species, *M. hemilecanii*, sp. n., appear to be closely related to *M. parvus*, Mercet. The narrow scape in combination with the four-jointed maxillary palpi and three-jointed labial palpi are the principal diagnostic characters by which these three species can be identified. According to Mercet's description, in *M. parvus* the fore wings are very narrow, while the two new species have fore wings of average width, slightly less than two and one-half times as long as wide. In *M. parvus* and *M. hemilecanii*, sp. n., the frontovertex is about three times as long as wide.

♀. Frontovertex about twice as long as wide. Ocelli in an acute triangle; anterior ocellus about twice its own diameter from the orbits; posterior pair about once their own diameter apart and one-half their own diameter from the orbits. Scrobes narrow and triangular. Scape about five times as long as wide; pedicel almost three times as long as wide, as long as the first four funicle joints united; first four funicle joints subequal, each about as wide as long or a trifle wider than long; sixth funicle joint about twice as wide as long; club twice as long as wide and as long as the five preceding funicle joints united. Scutellum as long as wide and as long as mesoscutum; on the sides of the latter the parapsidal furrows are slightly indicated. Abdomen about as long as the thorax; ovipositor sheaths about as long as the spur of middle tibiae.

Fore wings about two and one-half times as long as wide (41 : 16); densely covered with brown hairs. Speculum interrupted by five rows of hairs; the basal, cut-off portion separated by approximately its own length and appearing as if connected with the posterior marginal bare streak. The basal, cut-off portion and posterior marginal bare streak are not actually continuous, being separated by some microscopic, colourless hairs that are not evident under usual magnification.

Frontovertex yellowish; face and cheeks whitish; occiput largely blackish above the foramen with the margins pale. Radical joint and scape largely pale yellowish white with the dorsal margin of the latter blackish; pedicel largely concolorous with scape and somewhat brownish or slightly blackish at the base; first four funicle joints largely, if not entirely, brownish or blackish; fifth and sixth funicle joints yellowish white; the contrast in colour between the basal and apical funicle joints not abrupt or clearly defined; club grading from brownish or blackish basally to yellowish apically. Collar of pronotum white with a dark dot on either corner and the concealed part blackish. Mesoscutum, axillae, and scutellum yellow with the anterior part of mesoscutum and the sutures separating it from the axillae, as well as the sutures between axillae and scutellum, blackish; metanotum and propodeum mesad of spiracles blackish; tergum of abdomen, except lateral margins and apex, brownish; pleura and sternum of thorax and venter of abdomen white or largely so. Middle and hind tibiae tipped at ends with blackish or brown and with two pairs of spots almost coalescing and band like; front tibiae less distinctly marked with brown; middle femora with a distinct brown or blackish spot on ventral aspect near apex. Ovipositor sheaths pale yellowish white.

Length, 1·9 mm.

♂. Except for smaller size, difference in the antennae, and the usual sexual differences, the ♂♂ greatly resemble the ♀♀.

Scape and pedicel quite similar to that of ♀; first four funicle joints subequal in length and progressively slightly increasing in width, so that the fourth is one and one-fourth times as wide as the first ; sixth funicle joint about one and one-half times as wide as long and almost twice as wide as the first ; club twice as long as wide and only slightly wider than the sixth funicle joint.

Described from 9 ♀♀ and 9 ♂♂, holotype, allotype, and paratypes, collected by E. W. Rust as follows : 6 ♀♀ and 7 ♂♂ reared from a *Ceroplastes* sp. on " umkavoti " (*Chaetocme aristata*, Planch.), Durban, Natal, 25.i.1927, and 9.ii.1927 ; 2 ♀♀ from *Saissetia perseae*, Brain, Amanzimtoti, Natal ; 1 ♀ and 2 ♂♂, Durban, Natal. All these specimens are mounted in balsam and bear Rust's No. B 17.

6. **Metaphycus hemilecanii,** sp. n. (fig. 1).

This species is mentioned in the introductory paragraph of the preceding description.

♀. Frontovertex three times as long as wide. Ocelli in a strongly acute triangle ; anterior ocellus about its own diameter from the orbits ; posterior pair separated from each other by about once their own diameter and almost touching the orbits. The heads of the specimens mounted on tags have collapsed. The scrobes appear to be narrow and triangular. Eyes plainly hairy. Scape about five times as long as wide ; pedicel slightly more than twice as long as wide, as long as the first three funicle joints united ; first four funicle joints almost subequal, the first as wide as long, and the fourth plainly wider than long ; sixth funicle joint plainly wider than long (11 : 9) ; club more than twice as long as wide, about as long as the preceding five funicle joints. Scutellum as wide as long and slightly shorter than the mesoscutum. Abdomen, in tag mounts, much shorter than the thorax and rounded at apex ; ovipositor shortly exserted.

Fore wings slightly more than twice as long as wide (11 : 5). Speculum interrupted by six rows of hairs ; the basal, cut-off portion separated by more than its own length and under ordinary magnification appearing as if continuous with the posterior marginal bare streak.

Frontovertex orange-yellow ; face whitish ; cheeks yellow to whitish with a blackish blotch near oral margin and another blackish brown spot on the high temples. Occiput largely blackish above the foramen, with the margins white. Scape largely white with a distinct blackish brown streak on outer dorsal aspect extending from base to apex ; pedicel blackish brown on basal one-third, grading to whitish apically ; first four funicle joints and basal portion of club blackish brown ; fifth and sixth funicle joints whitish. Collar of pronotum white with a dark dot on either corner and the concealed part blackish. Mesoscutum, axillae, and scutellum yellowish ; in some specimens suffused with pale brown and in others golden. Concealed anterior part of mesoscutum and the sutures separating mesoscutum and axillae blackish. Metanotum, propodeum mesad of spiracles, and tergum of abdomen, except the sides, largely blackish brown. Pleura and sternum of thorax and venter of abdomen largely whitish with the mesosternum often brown or blackish. Legs conspicuously marked with blackish ; femora of middle and hind legs with a dark spot on ventral aspect near apex ; middle and hind tibiae tipped at ends and with two pairs of large blackish spots which may be confluent ; front tibiae tipped at ends and with one pair of large suffused blackish spots.

Length, 1·6 mm.

♂. Very similar to the ♀.

Described from 31 ♀♀ and 18 ♂♂, holotype, allotype, and paratypes, collected by E. W. Rust as follows : 20 ♀♀ and 18 ♂♂, mounted in balsam, from *Hemilecanium* sp., Durban, Natal, 23–24.ii.1925 ; 11 ♀♀, now mounted on tags that were found in a vial among Rust's unmounted specimens and labelled " ex mealybug-like scale on *Gardenia*. No. B 17." The specimens mounted by Rust on slides bear the No. B 17 and may be from the same rearing as those found in the vial.

One ♀ reared from *Asterolecanium* sp. on coffee, Kiambu, Kenya Colony, 27.ii.1931, by Dr. R. H. Le Pelley, appears to be indistinguishable from the specimens of the type series. The Kenya specimen bears Le Pelley's No. 393 and Ferrière's No. 22.

7. **Metaphycus lepelleyi,** sp. n. (fig. 1).

This species does not have any single diagnostic character by which it can be identified. Of the African species it appears most closely related to *M. lounsburyi* (Howard), from which it is easily distinguished by the characters given in the key.

♀. Frontovertex very narrow, slightly more than three times as long as wide. Ocelli in a strongly acute triangle ; anterior ocellus its own diameter from the orbits ; posterior pair about once their own diameter apart, very close to the orbits, and about twice their own diameter from the occipital margin. Eyes plainly hairy. Scape about two and one-half times as long as wide, ventral margin with a slight incision near the widest part ; pedicel about twice as long as wide ; first funicle joint slightly wider than long (5 : 4) ; sixth funicle joint much wider than long (10 : 7) ; club about twice as long as wide, rounded at apex, and as long as the preceding three funicle joints united. Parapsidal lines distinct, almost transverse, and disappearing toward the meson. Abdomen short ; ovipositor concealed ; the sheaths plainly shorter than the spur of middle tibiae.

Fore wings slightly less than two and one-half times as long as wide and finely and densely hairy. Speculum interrupted by three rows of hairs ; the basal, cut-off portion separated by more than its own length and widely separated from the posterior marginal bare streak.

Frontovertex cadmium-yellow ; face and cheeks white. Mesoscutum, axillae, and scutellum golden yellow and covered with numerous fine, appressed white hairs. Collar of pronotum white with a dark spot on either corner and the anterior concealed part of pronotum blackish. Metanotum, propodeum, mesad of spiracles, and most of tergum of abdomen brown ; the basal corners and lateral margins of abdomen posterior to the vibrissal plates whitish. Pleura and sternum of thorax and venter of abdomen white. Legs largely white, yellowish toward the tarsi, and distinctly spotted or banded with blackish ; middle and hind tibiae tipped at distal ends with blackish and each with two pairs of spots ; front tibiae not so distinctly marked with blackish and more suffused.

Length, 1·4 mm.

Described from 1 ♀, holotype, reared by Dr. R. H. Le Pelley from *Saissetia subhemisphaerica*, Kiambu, Kenya Colony, 26.ii.1931. This specimen bears Le Pelley's No. 459 and Ferrière's No. 21.

The major portion of the preceding description was made from the specimen when mounted on a tag. The specimen was then cleared and mounted in balsam.

8. **Metaphycus lounsburyi** (Howard) (fig. 2).

Aphycus lounsburyi, Howard, U.S. Natl. Mus. Proc. **21**, 1898, pp. 241–44 ; Smith and Compere, Univ. Calif. Publ. Entom. **4** (9), 1928, pp. 275–91.

A detailed account of this well-known species is given in the article by Smith and Compere, cited above.

9. **Metaphycus mauritanicus,** sp. n. (fig. 2).

This is a well-defined species not likely to be confused with any of the described forms. The three-jointed maxillary and labial palpi decisively separate it from the great majority of species. In the key it is placed next to *M. stanleyi*, sp. n., for convenience. However, these two species are not very much alike.

♀. Frontovertex about one and one-half times as long as wide (18 : 11). Ocelli in an acute triangle ; anterior ocellus almost twice its own diameter from the orbits ; posterior ocelli slightly less than their own diameter from the orbits and almost twice as far from the occipital margin. Eyes with conspicuous, fine white hairs. Scape about four times as long as wide (22 : 5) ; pedicel twice as long as wide ;

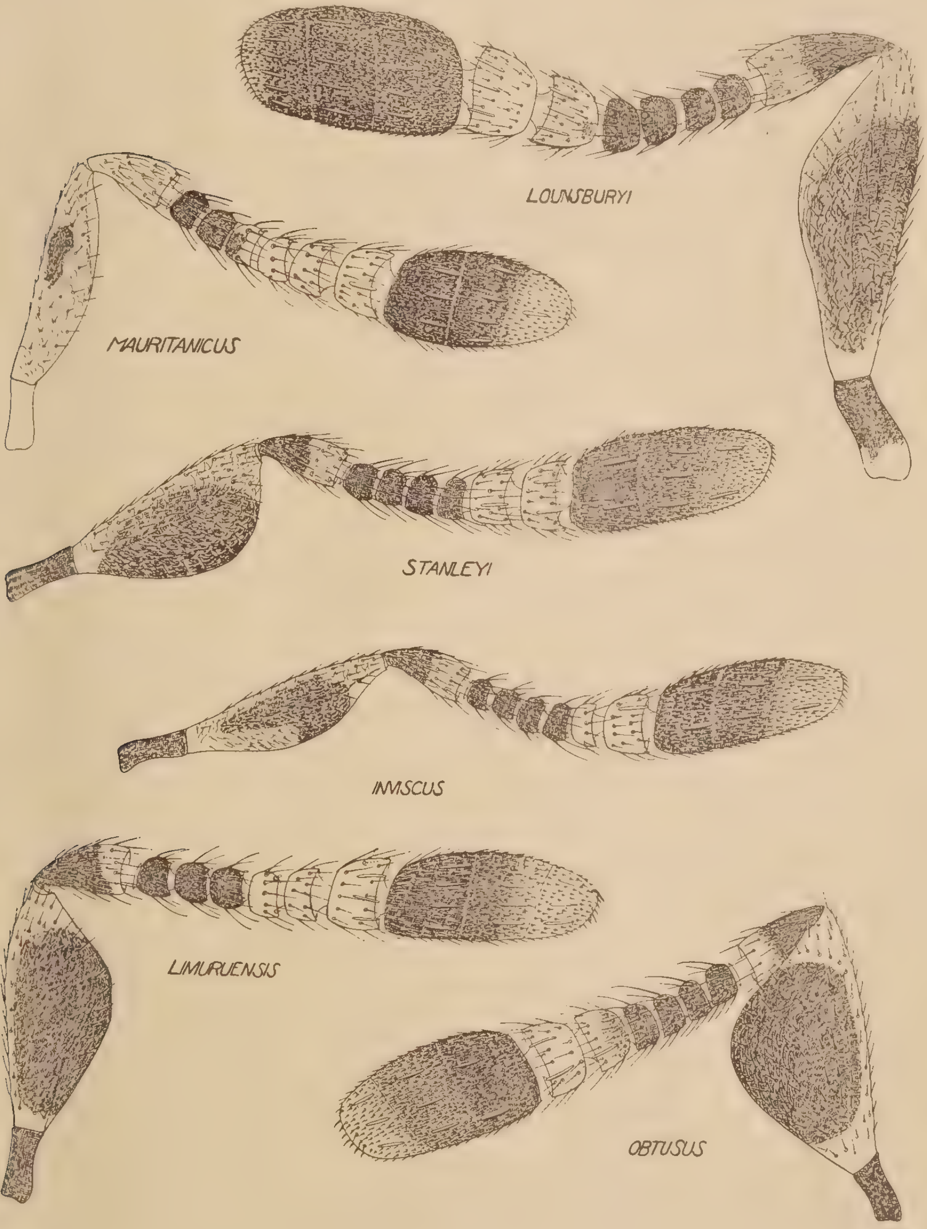
LOUNSBURYI
MAURITANICUS
STANLEYI
INVISCUS
LIMURUENSIS
OBTUSUS

Fig. 2. *Metaphycus* spp., ♀♀ ; antennae.

first funicle joint one and one-third times as wide as long ; sixth funicle joint slightly wider than long (6 : 5) ; club twice as long as wide, rounded at apex and slightly longer than the four preceding funicle joints united. Parapsidal sutures visible as fine lines on the sides of the mesocutum. Ovipositor not exserted, as seen in tag mounts.

Speculum interrupted by three rows of hairs ; the basal, cut-off portion large and separated by more than its own length.

Frontovertex pale lemon-yellow ; face and cheeks white ; occiput not partly blackish as in most species. Radical joint and scape white, the latter with an elongated blackish spot on the outer dorsal aspect distad of the middle ; pedicel almost completely white, the basal end faintly dusky ; first three funicle joints and first two club joints blackish ; distal three funicle joints and apical club joint white. Collar of pronotum white with a faint brown dot on either corner ; anterior, concealed part of pronotum blackish. Mesoscutum, axillae, and scutellum, slightly darker yellow than the frontovertex. Metanotum, propodeum, and abdomen pale yellow. Pleura and sternum of thorax whitish. Legs whitish without dark spots or suffusions.

Length, 1·0 mm.

Described from 1 ♀, holotype, bearing the following data on the label : " Fès, Maroc, 25.x.1937, Fieuzet elv." This specimen was received for identification from Dr. P. Regnier, Chef du Service de la Défense des Végétaux. It was obtained from *Coccus hesperidum*, Linn., infesting *Rhus coriaria*, L., by C. A. Bléton, the regional inspector.

The above description was made from the specimen when mounted on a tag. It was later boiled, cleared, and mounted in balsam.

10. **Metaphycus stanleyi,** sp. n. (fig. 2).

Metaphycus stanleyi, Compere, Univ. Calif. Publ. Entom. (In press).

This species was obtained from *Saissetia oleae* (Bern.), collected by the writer in Cape Town. The parasite was introduced into California in the same year and appears to be permanently established in this State. In South Africa it was also reared from *Coccus hesperidum*, Linn., collected at Uitenhage, 12.i.1937. What appears to be the same species is represented by 8 ♀♀ reared from *Saissetia nigra* (Nietn.), collected by Dr. R. Le Pulley at Kiambu, Kenya Colony, 16.ii.1931. These specimens bear Le Pelley's No. 374 and Ferrière's No. 1. A single ♂ reared from *Saissetia subhemisphaerica*, Kiambu, 11.xi.1930, and bearing Le Pelley's No. 424, is doubtfully referred to *Metaphycus stanleyi*.

11. **Metaphycus inviscus,** sp. n. (fig. 2).

This species is very similar to *M. limuruensis*, sp. n., *M. obtusus*, sp. n., *M. truncatus*, sp. n., and *M. insidiosus*, Mercet, from which it can be distinguished by the comparatively narrow scape in combination with several other characters.

♀. Frontovertex between two and three times as long as wide (the heads have collapsed and are distorted so that an accurate measurement cannot be made). Ocelli in an acute triangle. Scape moderately narrow and more than three times as long as wide (20 : 6) ; pedicel slightly more than twice as long as wide ; all funicle joints about one and one-half times as wide as long, the sixth almost twice as long as the first ; club slightly more than two and one-half times as long as wide (18 : 7), as long as the preceding five funicle joints. Eyes almost imperceptibly hairy. Parapsidal lines faintly visible in tag-mounted specimens. Ovipositor not exserted ; the sheaths about as long as the spur of middle tibiae. Integument of mesoscutum, axillae, scutellum, and tergum of abdomen with compound sculpture ; the reticulated lines enclosing secondary, faint aciculations.

Speculum interrupted by three rows of hairs ; the basal, cut-off portion separated by less than its own length.

Frontovertex orange-yellow ; face and cheeks pale yellowish white and with a blackish brown band on cheeks extending to the oral margin ; occiput largely blackish above the foramen. Scape with the inner and outer aspects largely blackish and the ends and dorsal margin broadly white ; basal half of pedicel, first four funicle joints, and club, except the apex, black ; apical half of pedicel and fifth and sixth funicle joints white. Concealed part of pronotum black ; the collar white with a dark dot on either corner. Mesoscutum, axillae, and scutellum largely golden to orange yellow with some brownish ; the anterior third of mesoscutum, sides narrowly, and posterior sutures blackish. Metanotum and propodeum mesad of spiracles blackish. Pleura and sternum of thorax largely white with some blackish, especially on the mesosternum. Tergum of abdomen largely blackish brown with sides pale. Tibiae of middle and hind legs blackish at the ends and with two wide conspicuous bands ; front tibiae less distinctly marked with blackish ; femora of middle and hind legs suffused with dusky toward distal ends on the ventral aspect.

Length, 1·0 mm.

Described from 3 ♀♀, holotype and paratypes ; 2 ♀♀ from *Saissetia oleae* (Bern.) on oleanders, Cape Town, xi.1936, H. Compere ; 1 ♀ reared at Riverside, California, 4.vi.1924, from *Saissetia oleae* material collected by E. W. Rust in Cape Town.

12. **Metaphycus limuruensis,** sp. n. (fig. 2).

This species, reared from *Ceroplastes* sp., appears to have a longer ovipositor, relative to the length of the abdomen, than the other closely related African species. As seen through the integument in the cleared, balsam-mounted specimen, the ovipositor extends the entire length of the abdomen.

♀. Frontovertex slightly more than twice as long as wide (7 : 3). Ocelli in an acute triangle ; anterior ocellus about its own diameter from the orbits ; posterior ocelli once their own diameter apart and about one-half their own diameter from the orbits. Eyes densely covered with fine white hairs. Scape almost two and one-half times as long as wide (24 : 10) ; pedicel twice as long as wide ; first four funicle joints subequal in length and each about one and one-third times as wide as long ; sixth funicle joint not much wider than long ; club slightly more than twice as long as wide, rounded at apex, and as long as the preceding five funicle joints united. In tag-mounted specimens the abdomen appears much shorter than the thorax ; in cleared specimens, mounted in balsam, the abdomen is as long as the thorax and the ovipositor as long as the abdomen. Ovipositor sheaths slightly shorter than the tibial spur of middle legs. Parapsidal lines not visible in tag-mounted specimens and in cleared specimens evident as short lines of thinner integument.

Speculum interrupted by six rows of hairs ; the basal, cut-off portion small, separated by more than its own length, and widely separated from the posterior marginal bare streak.

Frontovertex yellow with some whitish suffusions and with faint golden reflections ; face and cheeks largely white to yellowish with a broad, blackish brown band across the latter ; occiput largely blackish above the foramen. Scape largely black with the ends and dorsal margin white ; basal half of pedicel, first three funicle joints, and basal half of club blackish or dark brown ; apical half of pedicel and distal three funicle joints white ; club pale yellow apically. Concealed part of pronotum blackish ; the collar white with a dark dot on either corner. Mesoscutum, axillae, and scutellum cadmium-yellow with anterior concealed part of the mesoscutum blackish ; mesoscutar-axillar sutures blackish laterally. Pleura and sternum of thorax and venter of abdomen whitish. Metanotum, propodeum mesad of spiracles, and tergum of abdomen, except the sides, black to dark brown. Middle tibiae tipped at ends and with two wide, distinct blackish bands ; hind tibiae tipped at base and partially encircled by two wide bands or pairs of dots ; front tibiae suffused with brown near basal end ; middle and hind femora suffused with brownish on ventral aspect towards the apical ends.

Length, 1·3 mm.

Described from 2 ♀♀, holotype and paratype, the holotype on a tag and the paratype cleared and mounted in balsam. These specimens were received for identification from Dr. Norman S. Noble, Department of Agriculture, New South Wales. They are labelled " From *Ceroplastes* sp., mature on coffee, Limuru, Kenya Colony, 3.iii.1936 " and bear Noble's identification No. 9. A third, poorly preserved specimen of another species was included under this number.

13. Metaphycus obtusus, sp. n. (fig. 2).

This and the following species, *M. truncatus*, sp. n., are very much alike.

♀. Frontovertex two and one-half times as long as wide. Ocelli in a strongly acute triangle ; anterior ocellus about its own diameter from the orbits ; posterior ocelli about once their own diameter apart and less than one-half their diameter from the orbits. Eyes finely but plainly hairy. Scrobes semicircular above. Scape twice as long as wide ; pedicel twice as long as wide, as long as the first three funicle joints ; first funicle joint a trifle wider than long (6 : 5) ; the joints increase successively in width, so that the fourth is more than one and one-half times as wide as long (8 : 5) ; sixth funicle joint one and one-half times as wide as long ; club almost twice as long as wide (17 : 9), as long as the preceding five funicle joints united, widest basally, and tapering toward the bluntly rounded apex. Abdomen shorter than the thorax and rounded at apex ; ovipositor concealed or very shortly exserted.

Fore wings slightly more than twice as long as wide (55 : 26). Speculum interrupted by about five rows of hairs ; the basal, cut-off portion small and sometimes scarcely developed.

Frontovertex yellowish with the face and cheeks paler, and the latter broadly blackish adjacent to the oral margin ; occiput blackish above foramen. Radical joint black ; scape largely black with the ends and dorsal margin yellowish or whitish ; basal half of scape, first four funicle joints, and club, except apex, blackish ; fifth funicle joint white or yellowish or more or less suffused with blackish ; apical half of pedicel, sixth funicle joint, and apex of club yellowish or whitish. Concealed part of pronotum blackish ; the collar white with a dark dot on either corner. Mesoscutum, axillae, and scutellum yellow with the anterior portion of mesoscutum and its posterior sutures blackish. Sides of mesoscutum with transverse parapsidal lines which appear blackish in tag-mounted specimens. Pleura and sternum of thorax largely yellow with some admixture of whitish, the whitish especially pronounced on prepectus, anterior of mesopleura, and on sides of propodeum. Metanotum, propodeum mesad of spiracles, and tergum of abdomen largely blackish ; sides and venter of abdomen pallid white. Legs yellowish to whitish with conspicuous dark markings ; middle and hind tibiae blackish at ends and with two incomplete bands ; front tibiae with an irregular suffusion largely occupying basal half or more ; femora of middle and hind legs with some dusky on ventral margins.

Length, 1·1 mm.

♂. Frontovertex less than twice as long as wide. Ocelli large and arranged in an acute triangle ; anterior ocellus slightly more than its own diameter from the orbits ; posterior ocelli about once their own diameter apart and about one-half their diameter from the orbital and occipital margins. Scape about three times as long as wide ; pedicel slightly less than twice as long as wide ; first funicle joint a trifle wider than long and the sixth almost twice as wide as long ; club slightly more than twice as long as wide and as long as the preceding four funicle joints united. Eyes hairy.

Frontovertex yellow or orange and usually blackish brown between the ocelli; cheeks largely blackish; face yellow with some blackish above the oral margin. Scape pale brownish yellow to whitish with an elongated, suffused dark spot on either side; pedicel blackish basally and yellow apically; funicle and club blackish brown with some intrusions of yellowish. Except for the tegulae and lateral margins of the mesoscutum, the notum of thorax and tergum of abdomen blackish brown. Pleura and sternum of thorax largely pale brownish yellow with admixtures of whitish and blackish on mesosternum. Legs pale brownish yellow; all tibiae tipped at ends with blackish and the middle and hind tibiae with two blackish brown bands; front tibiae less distinctly marked.

Length, 1·3 mm.

Described from 23 ♀♀ and 13 ♂♂, holotype, allotype, and paratypes, reared from *Saissetia persimilis*, Brain, by E. W. Rust, Durban, Natal, 17.ii.1927. These specimens bear Rust's No. B 16.

14. Metaphycus truncatus, sp. n. (fig. 3).

This species, especially in the ♀ sex, is very similar to the preceding species, *M. obtusus*. In addition to the differences which are mentioned in the key, there are differences in the sculpture of the integument and, apparently, in the proportions of the heads.

♀. Frontovertex twice as long as wide. Ocelli in an acute triangle, much less acute than in *M. obtusus*; anterior ocellus one and one-half times its own diameter from the orbits; posterior ocelli almost twice their own diameter apart and fully one-half their own diameter from the orbits. Scape slightly more than twice as long as wide (7 : 3); pedicel twice as long as wide, as long as the first three funicle joints combined; first four funicle joints slightly unequal—the first, one and one-third times as wide as long, and the fourth, more than one and one-half times as wide as long (5 : 3); sixth funicle joint almost twice as wide as long (9 : 5) and not much longer than the first; club about one and one-half times as long as wide (10 : 7), increasing slightly in width from base to apex and broadly truncate at apex. Abdomen much shorter than the thorax; ovipositor not exserted.

Fore wings slightly more than twice as long as wide (16 : 7). Speculum interrupted by two or three rows of hairs; the basal, cut-off portion large and distinct.

Frontovertex lemon-yellow; face and cheeks largely whitish with the latter blackish near the oral margin; occiput black above the foramen. Radical joint dark brown; scape black with the ends whitish or yellow; basal half of pedicel, first four funicle joints, and first two club joints blackish; apical half of pedicel, fifth and sixth funicle joints, and apical club joint whitish or yellow. Concealed part of pronotum black; the collar white with a dark dot on either corner. Mesoscutum, axillae, and scutellum yellow, with the mesoscutum blackish anteriorly and along the mesoscutar-axillar sutures. Parapsidal lines visible but not marked with blackish. Pleura and sternum of thorax and venter of abdomen pale yellow to whitish. Metanotum, propodeum mesad of spiracles, and tergum of abdomen largely blackish; the last yellowish white on sides. Legs yellowish white with dark bands; middle tibiae with two incomplete bands; hind tibiae with two suffused spots; front tibiae very faintly suffused near the base.

Length, 1·3 mm.

♂. Frontovertex plainly wider than in *M. obtusus*, but the head of the only entire ♂ specimen, allotype, is partly collapsed, and an accurate measurement cannot be made. Presumably the ocelli are in an equilateral triangle. Scape almost twice as long as wide; pedicel twice as long as wide; first funicle joint as wide as long; sixth funicle joint almost one and one-half times as wide as long; club less than twice as long as wide (15 : 9) and narrowly semitruncate at apex.

Frontovertex orange-yellow with some blackish near the occipital margin; cheeks largely blackish; face pale yellowish white. Scape black with the ends whitish; basal third of pedicel blackish and the apical portion yellowish; funicle joints and club brownish yellow. Pronotum largely black with collar very narrowly yellowish white and a dark dot on either corner. Notum of thorax and tergum of abdomen blackish to brown with admixtures of yellow on the margins of the sclerites.

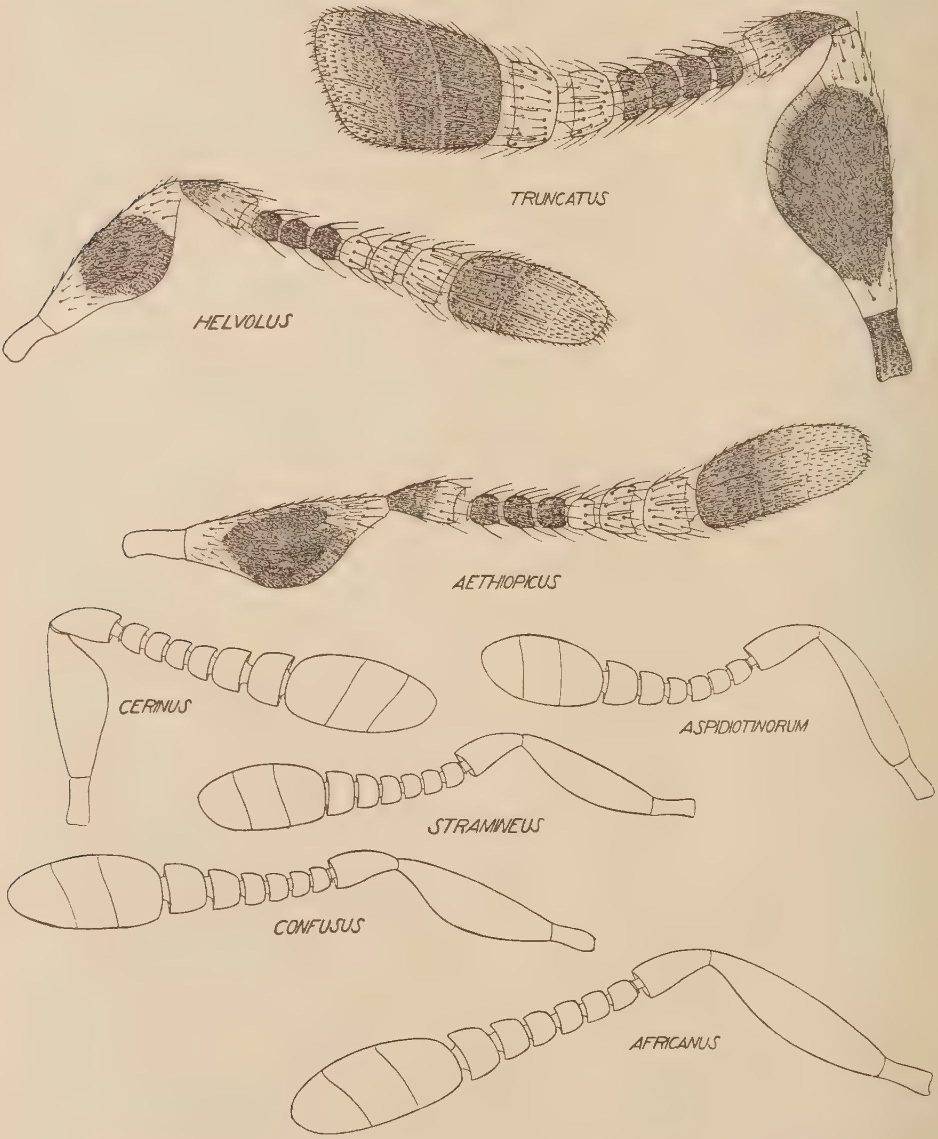
TRUNCATUS
HELVOLUS
AETHIOPICUS
CERINUS
ASPIDIOTINORUM
STRAMINEUS
CONFUSUS
AFRICANUS

Fig. 3. *Metaphycus* spp., ♀♀; antennae. (The unshaded drawings were made from uncleared specimens. The shaded drawings of this and preceding figures were made from cleared specimens.)

Middle tibiae with distinct brown bands; front and hind tibiae not distinctly spotted or banded.

Length, 1·1 mm.

Described from 6 ♀♀ and 2 ♂♂ hollotype, allotype, and paratypes, reared from *Pulvinaria jacksoni*, Newst., by E. W. Rust, Durban, Natal, 12.vi.1926.

One ♀, without host data, collected by the writer in Uganda, vi.1937, is identified as *Metaphycus truncatus*. The specimen from Uganda has the antennal club more rounded at the apex than in the specimens from Natal.

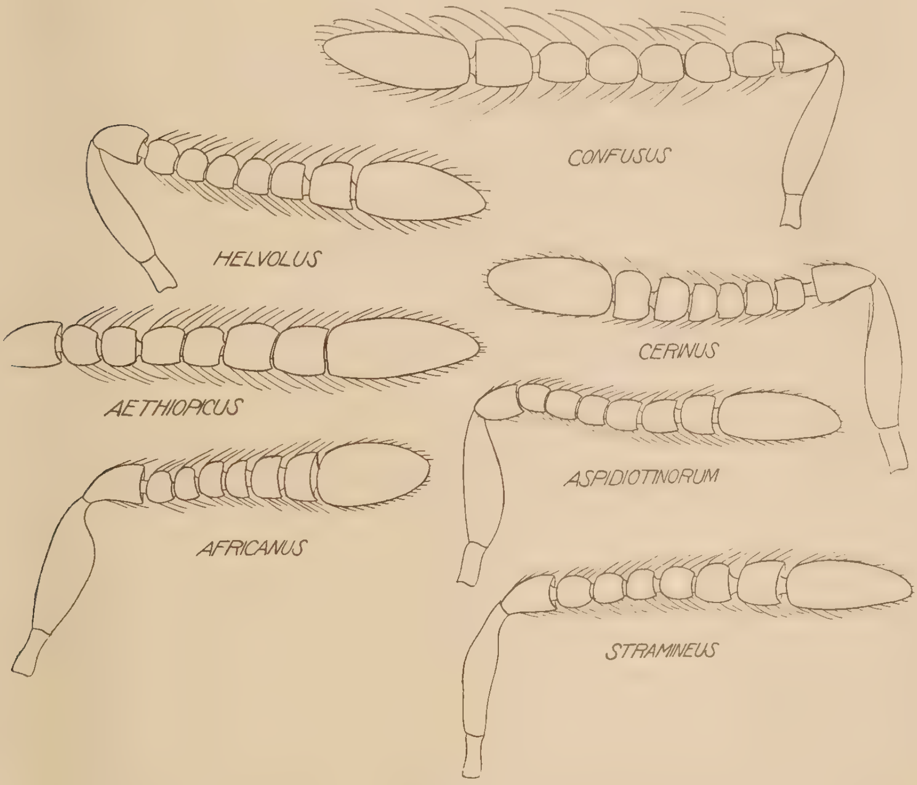

Fig. 4. *Metaphycus* spp., ♂♂; antennae.

15. **Metaphycus aspidiotinorum,** sp. n. (figs. 3, 4).

M. aspidiotinorum belongs to a group of closely related species which is represented by *M. hederaceus* (Westwood), *M. pinicola* (Mercet), *M. pretiosus* (Mercet), and *M. ibericus* (Mercet). This group of species is characterized by the unusually slender scape, which is attenuated distally. The four species studied by Mercet are described as having both the middle and hind tibiae marked with black bands. In *M. aspidiotinorum* the hind tibiae are often immaculate, or nearly so, and the middle tibiae are either distinctly or faintly spotted with brown. Following the description, a key to the species of the *hederaceus* group, based largely on that of Mercet, is given in order to indicate more concisely the characters by which *M. aspidiotinorum* may be distinguished.

♀. Frontovertex slightly less than twice as long as wide. Ocelli in an acute triangle ; anterior ocellus almost twice its own diameter from the orbits ; posterior ocelli almost their own diameter from the orbital and occipital margins and about one and one-half times their own diameter apart. Scape very narrow, neither compressed nor expanded below, approximately five times as long as wide, and gradually tapering from about the middle to the apex ; pedicel about twice as long slightly wider than long ; club large, ovate, ranging from slightly less than two to as wide ; first funicle joint about as long as wide ; sixth funicle joint as wide as or two and one-half times as long as wide, and about as long as the preceding five funicle joints united.

Fore wings slightly more than two and one-half times as long as wide (48 : 19) ; longest hairs of the marginal fringe measuring from 0·02 mm. to 0·03 mm. in length and those most widely spaced, 0·015 mm. from each other. Speculum narrowed above and interrupted near the middle of blade by a variable number of exceedingly small and very irregularly placed hairs. In the specimens reared from *Aspidiotus lounsburyi* (Marlatt), the hairs which interrupt the speculum are more coarse and more numerous and arranged in four irregular rows. Basal, cut-off portion of speculum large and separated by about its own length.

Hind wings with the longest hairs of the marginal fringe more than one-half the greatest width of the blade. In the specimens from Natal, reared from *Chionaspis natalensis*, Mask., the marginal fringe is slightly longer than in the specimens of the other series.

Abdomen about as long as the thorax ; ovipositor, as seen through the integument, about as long as the abdomen and plainly longer than the length of middle tibiae ; ovipositor exserted and the sheaths about as long as the spur of middle tibiae.

General colour pale lemon-yellow to whitish. Occiput largely blackish above the foramen ; pronotum variable, the collar white or yellowish with dark dots on the corners, and the concealed anterior portion extensively blackish. In some specimens the anterior margin of mesoscutum, the metanotum, and propodeum mesad of spiracles are brown or blackish. Scape colourless or yellowish white with a brown or blackish suffusion on either side distad of the middle ; pedicel brown or blackish basally, grading to yellow apically ; first four funicle joints usually brownish and the fifth and sixth yellowish, with the change in coloration gradual and variable ; basal portion of club blackish, grading to yellow or whitish apically. Legs pale yellow to whitish or colourless ; the middle tibiae either plainly or indistinctly marked with two pairs of brown spots ; hind tibiae with or without distinct dark markings.

Length, 0·8 mm. or smaller.

♂. Frontovertex slightly less than one and one-half times as long as wide (8 : 6). Ocelli in an acute triangle. Scape about three times as long as wide ; pedicel less than twice as long as wide (5 : 3) ; first funicle joint slightly wider than long ; the sixth with the same relative proportions as the first ; club more than twice as long as wide (10 : 4) and slightly longer than the three preceding funicle joints united. Flagellum with colourless hairs.

Described from 65 ♀♀ and 25 ♂♂, holotype, allotype, and paratypes, reared by E. W. Rust as follows : 45 ♀♀ and 10 ♂♂ from *Aspidiotus lounsburyi* (Marlatt), Mowbray, Cape Town, 6.vii.1925 ; 16 ♀♀ and 14 ♂♂ from *Chionaspis margaritae*, Brain, Camp's Bay, Cape Town, 5.vi.vii.1925 ; 4 ♀♀ and 1 ♂ from *Chionaspis natalensis*, Mask., Tsetse Fly Lab., Zululand, Natal, xii.1925. The first two series of specimens bear Rust's No. K 3 and the third series of specimens, his No. B 22.

In a preliminary draft of this paper the specimens mentioned as types were segregated and considered as representatives of at least two distinct species. The specimens from Natal, parasitic on *Chionaspis natalensis*, have a small but distinct integumentary infuscation beneath the marginal vein. The specimens from

Aspidiotus lounsburyi, collected in Cape Town, lack the fuscous spot beneath the marginal vein. The specimens reared from *Chionaspis margaritae*, collected in Cape Town, seem to be intermediate, the majority of specimens having a very faint cloud beneath the marginal vein. Also, in the Natal specimens the spur of the middle tibiae is more sharply pointed than in the Cape Town specimens, and in the ♂♂ the funicle joints appear wider relative to length.

The principal diagnostic characters for separating ♂ *Metaphycus aspidiotinorum*, sp. n., from ♂ *M. hederaceus* (Westwood) follow :—

M. aspidiotinorum, sp. n. ♂. Cheeks blackish posterior to the genal suture ; face and frontovertex orange-yellow. Scape colourless or whitish basally, grading to yellowish apically with a faint dark suffusion distad of the middle. Notum of thorax yellow with variable suffusions of brown or blackish. Abdomen largely yellow with the basal third faintly suffused with dusky. Tarsal segments of middle legs not unusually long and slender.

M. hederaceus (Westwood). ♂. Head and thorax lemon-yellow and the base of abdomen black. Scape white with brown on dorsal and ventral margins ; pedicel brown basally and whitish apically. Tibiae of middle and hind legs with two blackish bands. Tarsal segments of middle legs long and slender.

Key to the Species of the hederaceus *Group, Females.*

1. Notum of thorax yellow, reddish, or brownish, and the abdomen more or less of the same colour......2

Notum of thorax completely black ; pleura and sternum and abdomen white (Spain) ......*pretiosus* (Mercet)

2. Notum of thorax brown, concolorous with the abdomen......3

Notum of thorax yellow......4

3. Frontovertex twice as long as wide. Wings slightly smoky. Ovipositor exserted as long as the length of the spur of middle tibiae (Spain)......*ibericus* (Mercet)

Frontovertex slightly longer than wide. Wings hyaline. Ovipositor scarcely perceptible (British Isles, Spain)......*hederaceus* (Westwood)

4. Fore wings with the hairs of the marginal fringe short and placed very close together. Spur of middle tibiae thick......5

Fore wings with the hairs of the marginal fringe long (0·02 mm. to 0·03 mm.) and spaced widely apart (about 0·015 mm.). Spur of middle tibiae variable......6

5. Notum of thorax orange-yellow ; abdomen pale yellow. Hind wings with the longest hairs of the marginal fringe as long as the greatest width of the blade (Spain)......*botanicus* (Mercet)

Mesoscutum and scutellum orange-yellow ; metathorax dark brown ; abdomen yellow with the distal tergites blackish. Hind wings with the longest hairs of the marginal fringe shorter than the greatest width of the blade (Spain)...... *pinicola* (Mercet)

6. Frontovertex slightly longer than wide. Spur of middle tibiae long and slender. Inner aspect of basitarsus of middle legs with sharp spines only. According to Mercet's description and figure, the short, peg-like spines which are generally present in all species are absent, and the tibial spur is as long as the basitarsus (British Isles, Spain)......*hederaceus* (Westwood)

Frontovertex slightly less than twice as long as wide (7 : 4). Spur of middle tibiae variable. Inner aspect of basitarsus of middle legs not only with sharp spines but with the usual short, peg-like conical spines (Cape Province, Natal)... *aspidiotinorum*, sp. n.

16. Metaphycus stramineus, sp. n. (figs. 3, 4).

This species greatly resembles *M. luteolus* (Timberlake). These two species can be separated with certainty by the different number of joints in the palpi. *M. luteolus* belongs to the group of species having both maxillary and labial palpi three-jointed and it is not known to occur in Africa. These two species also differ in colour. In *M. luteolus* the collar of the pronotum is marked on either side by a small dark dot. In *M. stramineus* the pronotum is marked with brown or blackish from the sides of the collar to near the insertion of the neck.

♀. Frontovertex less than twice as long as wide. Ocelli in an acute triangle; posterior ocelli more than their own diameter apart. Scape narrow and about four times as long as wide; pedicel twice as long as wide; first funicle joint as wide as long and the sixth wider than long (4 : 3); club less than twice as long as wide (12 : 7), as long as the preceding five funicle joints united, and rounded at the apex.

Fore wings about two and one-half times as long as wide (44 : 17); the longest hairs of the marginal fringe measuring 0·025 mm. in length. Speculum narrowed above and interrupted by three rows of hairs; the basal, cut-off portion separated by less than its own length and not continuous with the posterior marginal bare streak. Hind wings with the longest hairs of the marginal fringe slightly longer than the greatest width of the blade.

Abdomen about as long as the thorax; ovipositor, as seen through the integument, about one-half as long as the abdomen and shortly exserted; ovipositor sheaths about as long as the spur of middle tibiae.

General colour pale lemon-yellow. Pronotum with the dark coloration of the anterior concealed portion extending to the corners of the collar. Margins of mesoscutum, except posteriorly, sides of axillae and scutellum, metanotum, and propodeum mesad of spiracles largely brownish. Occiput largely brown or blackish above the foramen. Radical joint brown; scape yellowish with an oblique brown suffusion near apex; base of pedicel, first three funicle joints, and basal half of club blackish to brown. Legs immaculate.

Length, 0·9 mm.

♂. Scape about three times as long as wide (13 : 4); pedicel one and one-half times as long as wide; first funicle joint as long as wide or slightly wider than long and the sixth plainly larger than the first and slightly longer than wide; club about three times as long as wide, as long as the three preceding funicle joints united.

Fore wings with relatively sparse and short hairs on the blade; marginal fringe short. Hind wings with the longest hairs of the marginal fringe slightly longer than one-half the greatest width of the blade.

Head, pleura and sternum of thorax, and most of abdomen pale yellow to whitish. Mesoscutum, axillae, scutellum, metanotum, and propodeum mesad of spiracles pale brown; tergum of abdomen slightly brownish. Scape with a faint, suffused brownish spot near the middle; flagellum brownish with the apical portion of scape yellowish. Legs yellowish white with faint dusky intrusions but without distinct spots or bands.

Length, 0·7 mm.

Described from 4 ♀♀ and 3 ♂♂, holotype, allotype, and paratypes, reared by E. W. Rust, as follows: 2 ♀♀ and 2 ♂♂ from *Pulvinaria mesembryanthemi* (Vallot), Rosebank, Cape Town, 3.iv.1925; 1 ♀ and 1 ♂ reared from *Saissetia oleae* (Bern.), Salt River, Cape Town, xii.1925, and iv.1925; 1 ♀ from *Chionaspis margaritae*, Brain, Camps Bay, Cape Town, v.1925. These specimens bear Rust's No. K 2.

17. Metaphycus praevidans (Silvestri).

Aphycus praevidans, Silvestri, Bol. Lab. Zool. Gen. e Agr. R. Scuola Super. Agr. Portici, **9,** 1914, pp. 295–97.

Aphycus praevidans, Mercet, Bol. R. Soc. Españ. Hist. Nat. **8,** 1917, p. 133.

None of the specimens at hand agree with Silvestri's description of *Metaphycus praevidans*. This species is described as having the tibiae of middle and hind legs with dark spots, the anterior part of mesoscutum and tergites 2–4 brownish, and the length of the scape, relative to width, in the ratio of 52 : 14.

18. Metaphycus helvolus (Compere) (figs. 3, 4).

Aphycus helvolus, Compere, Univ. Calif. Publ. Entom. **4** (1), 1926, pp. 25–29.

Euaphycus helvolus, Smith and Compere, Univ. Calif. Publ. Entom. **4** (9), 1928, p. 274.

This species is a rather common parasite of *Saissetia oleae* (Bern.) in Cape Town and vicinity. It was imported into California in 1937 and seems to have become established in the citrus orchards.

19. Metaphycus aethiopicus, sp. n. (figs. 3, 4).

It seems questionable whether the form described here as a new species is specifically distinct from *M. praevidans* (Silvestri). Silvestri's description is based on 2 ♀♀ and 1 ♂ obtained from *Philippia chrysophyllae*, collected at Nefasit, Eritrea. The form described here as a new species was reared from an unidentified Coccid infesting *Olea chrysophylla*, likewise collected at Nefasit, Eritrea. The specimens on which this description is based may have issued from *Philippia chrysophyllae*. Since the specimens at hand are not in entire agreement with Silvestri's description, they are described as new.

This species, as well as *Metaphycus praevidans* (Silvestri), can be separated from *M. helvolus* (Compere) by the presence of dark spots on the tibiae. *M. helvolus* has been propagated in the insectary at Riverside by the tens of thousands, and samples of this insectary-grown material, as well as numerous samples from the orchards, are composed of specimens which invariably have the legs immaculate.

♀. Frontovertex slightly more than one and one-half times as long as wide. Ocelli in an acute triangle ; anterior ocellus about twice its own diameter from the orbits ; posterior ocelli about one-half their own diameter from the occipital and orbital margins. Scape less than three times as long as wide (20 : 8) ; pedicel twice as long as wide ; first funicle joint as long as wide, and the sixth plainly wider than long ; club twice as long as wide, slightly shorter than the preceding five funicle joints, and rounded at apex.

Fore wings two and one-half times as long as wide ; marginal fringe short. Speculum interrupted by four or five rows of hairs ; the basal, cut-off portion separated by about its own length and not continuous with the posterior marginal bare streak.

Ovipositor, as seen through the integument, about one-half as long as the abdomen ; not exserted ; the sheaths shorter than the spur of middle tibiae.

General colour yellow with the face, cheeks, pleura and sternum of thorax, and venter of abdomen largely whitish. Concealed part of pronotum blackish ; the collar white with a dark dot on either corner. Occiput largely blackish above the foramen. Metanotum and propodeum mesad of spiracles blackish. Tergum of abdomen slightly dusky in the centre toward base. Scape black with the ends and dorsal margin white ; basal half of pedicel, first three funicle joints, and basal half of club blackish ; apical half of pedicel, distal three funicle joints, and apical part of club yellow to whitish. Legs white to yellowish with brown or blackish markings; tibiae of middle legs with two pairs of spots; tibiae of hind legs faintly spotted.

Length 0·9 mm.

♂. Notum of thorax yellow with brownish suffusions; tergum of abdomen largely blackish brown.

Described from 15 ♀♀ and 4 ♂♂, holotype, allotype, and paratypes, reared from an unidentified Coccid infesting *Olea chrysophylla*, Nefasit, Eritrea, iv.1930, H. Compere.

20. Metaphycus confusus, sp. n. (figs. 3, 4).

In the ♀♀ this form appears to be indistinguishable from *M. aethiopicus*, sp. n. The ♂♂, however, appear to be different.

♀. Frontovertex about one and one-half times as long as wide. Ocelli in slightly less than an equilateral triangle; anterior ocellus about twice its own diameter from the orbits; posterior ocelli about once their own diameter from the orbital and occipital margins. Scape about three times as long as wide; pedicel twice as long as wide; first funicle joint about as wide as long, and the sixth about one and one-half times as wide as long; club twice as long as wide, as long as the preceding five funicle joints combined, and rounded at apex.

Fore wings less than two and one-half times as long as wide; the longest hairs of the marginal fringe measuring 0·02 mm. in length. Speculum interrupted by three or four rows of hairs; the basal, cut-off portion separated by about its own length.

Abdomen shorter than the thorax. Ovipositor sheaths shorter than the length of tibial spur of middle legs.

General colour yellowish on the dorsum and whitish on the sides and ventral parts with the following parts blackish: occiput above the foramen, anterior concealed portion of pronotum, a dot on either corner of the collar, metanotum, and the propodeum mesad of the spiracles. Scape partly black, the ends broadly and the dorsal margin more or less pale yellowish or white; basal half of scape, first three or four funicle joints, and basal half of club blackish; apex of pedicel, apex of club, and the fifth and sixth funicle joints yellowish. Legs pale yellow to whitish with the middle tibiae faintly spotted with brown near the base and less distinctly spotted near the middle.

Length, ranging near 1·0 mm.

In the ♂ sex the species closely resembles *M. helvolus* (Compere). It differs from the latter by having the antennae more coarsely hairy, the funicle joints slightly longer relative to width, the tibiae of middle legs faintly marked with brown, and by the absence of integumentary infuscations which often darken the fore wings of *M. helvolus*. When the ♂♂ of *M. confusus* and *M. aethiopicus* are viewed side by side, the difference in the size, coarseness, and colour of the hairs which clothe the flagellum, is very striking. In the illustrations, however, the difference is not so noticeable because of the necessity of drawing colourless hairs in black.

♂. Frontovertex about as long as wide. Ocelli in an equilateral triangle; anterior ocellus about twice its own diameter from the orbits; posterior ocelli almost twice their own diameter apart and about once their own diameter from the orbital margin. Scape narrow and four times as long as wide; first funicle joint about as long as wide, and the sixth slightly longer than wide. Flagellum furnished with coarse brown hairs which are slightly curved; hairs on the funicle fully as long as the length of the segments from which they arise.

General colour orange with dark suffusions. Pronotum with the blackish coloration extending uninterruptedly from the corners of the collar to the insertion of the neck or interrupted by yellowish with the usual isolated dots on the corners of the collar. Notal sclerites of thorax yellow to pale brown with the anterior margin of mesoscutum, the metanotum, and propodeum mesad of spiracles, blackish. Sides of mesoscutum, axillae and scutellum, and the sutures between these sclerites more or less brown or blackish. Tergum of abdomen slightly suffused with blackish in the middle. Antennae yellow or brown, the scape marked with blackish near the middle, and the base of pedicel somewhat darker than the remainder of flagellum. Legs yellowish to whitish with dusky suffusions; tibiae of middle legs usually distinctly spotted near base and very faintly so near the middle.

Length 0·7 mm.

Described from 21 ♀♀ and 32 ♂♂, cotypes. These specimens are crowded on three slides and mounted in balsam. They were reared by E. W. Rust from an unidentified Coccid collected at Durban, Natal, vi.1927.

21. **Metaphycus cerinus**, sp. n. (figs. 3, 4).

Of assistance in identifying this species is the blackish coloration of the mesoscutar-axillar sutures which stand out in sharp contrast to the dominant yellow of the sclerites.

♀. Frontovertex about one and one-half times as long as wide. Ocelli in slightly less than an equilateral triangle; anterior ocellus about twice its own diameter from the orbits; posterior ocelli slightly less than once their own diameter from the orbits and about once their diameter from the occipital margin. Scape two and one-half times as long as wide; pedicel slightly less than twice as long as wide; first funicle joint ranging near one and one-half times as wide as long and the sixth almost twice as wide as long; club twice as long as wide, as long as the preceding five funicle joints united, and rounded at the apex.

Fore wings more than twice as long as wide (57 : 24); marginal fringe moderately short, the longest hairs measuring 0·02 mm. in length. Speculum interrupted by three or four rows of hairs; the basal cut-off portion separated by about its own length.

Ovipositor, as seen through the integument, about one-half as long as the abdomen; concealed or very shortly exserted; the sheaths as long as the spur of middle tibiae.

General colour yellow to whitish. Occiput blackish above the foramen. Scape largely black on either side of middle; the basal third, apex and dorsal margin yellowish white; basal half of pedicel, first three or four funicle joints, and basal half of club blackish; apex of pedicel, apex of club, and fifth and sixth funicle joints yellowish or whitish. Mesoscutum, axillae, and scutellum yellow except for the anterior margin of mesoscutum and the sutures between this sclerite and the axillae, which are blackish. Concealed anterior portion of pronotum black; the collar yellow or white with a black dot on either corner. Metanotum and propodeum mesad of spiracles blackish. Tergum of abdomen slightly suffused with blackish in the centre. Legs yellowish to whitish with faint spots on the middle tibiae near the basal ends.

Length, 1·2 mm.

♂. Frontovertex slightly longer than wide. Ocelli in an equilateral triangle; anterior ocellus fully twice its own diameter from the orbits; posterior pair about twice their own diameter apart and about once their diameter from the orbital margin. Scape three times as long as wide; pedicel one and one-half times as long as wide; first funicle joint as long as wide, and the sixth slightly wider than long; club less than three times as long as wide.

Coloration similar to that of ♀ except the antennae and legs. Scape pale yellow to whitish with indications of dusky distad of the middle; pedicel dusky basally and yellowish white apically; funicle joints and club pale brownish yellow.

Length, 0·6 mm. to 0·8 mm.

Described from 39 ♀♀ and 32 ♂♂, holotype, allotype, and paratypes, reared from *Filippia carissae*, Brain, Durban, Natal, 9.x.1925, and vii.1926, E. W. Rust.

22. Metaphycus africanus, sp. n. (figs. 3, 4).

If ♂♂ are lacking, this species will be very difficult to identify because of the close resemblance of the ♀♀ to certain other species. Morphologically this species appears to be very similar to *M. alberti* (Howard), a species known from New South Wales and California only. In *M. alberti* the notal sclerites of the thorax do not appear as if framed in blackish as in this species. Of the African species, *M. africanus* is most easily confused with *M. cerinus*, sp. n., especially in the absence of the ♂ sex. In this species the frontovertex appears to be narrower than in *M. cerinus*.

♀. Frontovertex a trifle more than twice as long as wide (13 : 6). Ocelli in a strongly acute triangle; anterior ocellus slightly more than its own diameter from the orbits; posterior ocelli about once their own diameter apart. Scape slightly more than three times as long as wide (17 : 5); pedicel slightly more than twice as long as wide (7 : 3); first funicle joint a trifle wider than long, and the sixth about one and one-half times as wide as long; club about twice as long as wide and rounded at the apex.

Speculum interrupted by four rows of hairs; the basal, cut-off portion separated by its own length. Hind wings with the longest hairs of the marginal fringe more than one-half as long as the greatest width of the blade (8 : 13).

Ovipositor, as seen through the integument, more than one-half the length of the abdomen and slightly longer than the length of middle tibiae; shortly exserted.

General colour yellow. Frontovertex a brighter yellow than the notum of thorax; the pleura and venter of thorax and most of abdomen paler than notum of thorax. Occiput largely blackish above the insertion of the neck; pronotum with the blackish extending uninterruptedly from the corners of the collar to near the neck. Margins of mesoscutum, sides of axillae and scutellum, posterior wing processes, metanotum, propodeum mesad of spiracles, and tergum of abdomen on either side at base, blackish or brown. Scape largely yellowish white with a wide, oblique black band on either side distad of the middle; basal half of pedicel, first three funicle joints, and basal two-thirds of club blackish or brown; apical half of pedicel, distal three funicle joints, and apex of club yellowish. Legs yellowish white without any indications of spotting on the middle tibiae.

Length, 0·9 mm.

A most valuable character for the identification of this species is the scape in the ♂ sex. In none of the closely related species is the scape so wide as in this form.

♂. Frontovertex slightly more than one and one-half times as long as wide. Ocelli large and in an equilateral triangle, or nearly so; anterior ocellus about one and one-half times its own diameter from the orbits; posterior ocelli about once their own diameter apart and one-half their diameter from the orbital and occipital margins. Scape about two and one-half times as long as wide, distinctly compressed and expanded ventrally; pedicel slightly less than twice as long as wide; first funicle joint as long as wide, and the sixth almost twice as wide as long; club slightly more than twice as long as wide. Flagellum with fine, pale hairs that are colourless or nearly so, and hardly visible under ordinary magnifications.

Scape black with the apical end yellowish white; pedicel blackish brown basally grading to yellow apically; funicle joints and club brown. Notum of thorax about as in the ♀ except for cut-off black dots on the corners of the pronotum. Tergum of abdomen largely brown. Tibiae of middle and hind legs faintly spotted near basal ends.

Length, 0·9 mm.

Described from 9 ♀♀ and 10 ♂♂, holotype, allotype, and paratypes, reared by E. W. Rust from an unidentified Coccid, Durban, Natal, 27.21.vi.1926.

23. Metaphycus subflavus, Timberlake.

Coccidencyrtus flavus, Ashmead, Can. Ent. **33,** 1901, p. 139.
Metaphycus subflavus, Timberlake, Proc. Haw. Ent. Soc. **6** (3), 1927, p. 517.

It is possible that one of the species described as new in this paper may be synonymous with *M. subflavus*, Timberlake. It is impossible to identify *M. subflavus* from Ashmead's original description. The type, which is in the United States National Museum, was inspected by P. H. Timberlake some years ago. Timberlake referred the species to *Metaphycus* and provided its new name *subflavus*, as *flavus* was preoccupied by Howard's species of the same name.

According to Ashmead's description, the species was reared by C. P. Lounsbury from a mealybug, *Dactylopius* sp., on gorse, collected in Cape Province, South Africa. This is the sole record of the rearing of a species of *Metaphycus* from a species of mealybug.

HYMENOPTEROUS PARASITES OF WILLOW INSECTS.

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Introduction.

The cricket-bat willow, *Salix alba* var. *caerulea*, Smith, is subject to the disease known as " watermark," caused by *Bacterium salicis* (Day), emend. Dowson, which renders the wood useless for bat manufacture. *B. salicis* is apparently restricted to the wood of the tree, and insects, which feed upon or inhabit the wood during a part of their life-cycle, are suspected of being involved in disease transmission. With a view to finding which insects were most likely to be responsible for the transmission of the disease, the writer undertook a survey of the insect fauna of the bat willow in the Eastern Counties of England during 1936 and 1937 on behalf of H.M. Forestry Commission and the Agricultural Research Council. In the course of this work a number of Hymenopterous parasites of willow insects were obtained. The nature of the work was such that the wood-inhabiting insects were studied rather than those feeding upon the leaves or sucking the sap. Incidental observations were occasionally made on insects other than those inhabiting the wood and on willows other than the bat willow. These, however, were few, and the majority of the records are of parasites bred from insects inhabiting the wood of the bat willow.

One or more specimens of all the Chalcidoidea and Proctotrupoidea and of all the Ichneumonoidea, except *Angitia vestigialis*, Ratz., and *Rhogas irregularis*, Nees, have been retained in the collection at the British Museum (Natural History).

Parasites of Wood-Inhabiting Insects.

Insects commonly found inhabiting the wood of the bat willow were the larvae of the gall-midges, *Rhabdophaga saliciperda*, Duf., and *Rhabdophaga* sp., and the sawfly, *Euura atra*, Jur., and these were most strongly suspected of being involved in the transmission of the " watermark " disease. *Rhabdophaga* sp. differs from *R. saliciperda* in a number of structural details, and is apparently an undescribed species. One of the most conspicuous of these structural differences is in the shape of the process at the base of the antennal sheaths in the pupa, to which Barnes (1935) assigns taxonomic value. In *Rhabdophaga* sp., the antennal sheaths in the pupa have a large triangular process at the base similar to that in *R. triandraperda*, Barnes, and not elongated and pointed as in *R. saliciperda*. The larva of *Rhabdophaga* sp. invariably inhabits the wood of young shoots and is almost always located near a bud, which becomes bright red and slightly swollen and fails to open.

Further support for the separation of *Rhabdophaga* sp. and *R. saliciperda* as distinct species is given by a study of their parasites. *Torymus pulchellus*, Thoms., *Tetrastichus roesellae*, DeG., and *Platygaster* sp., were the three parasites found most commonly attacking *Rhabdophaga* sp. None of these species was ever bred from *R. saliciperda*. On the other hand the most common species parasitizing *R. saliciperda* was *Eurytoma saliciperdae*, Mayr, which was never obtained from *Rhabdophaga* sp. The only parasite bred from both gall-midges was *Microterys clavellatus*, Dalm., and this appears to be the first record of this species attacking CECIDOMYIIDAE.

Parasites and hyperparasites bred from these wood-inhabiting species are listed below.

Host Species.	Parasites.	Notes.
Rhabdophaga sp. (Diptera, Cecidomyiidae).	*Torymus pulchellus*, Thoms. ...	abundant
	Eupelmus urozonus, Dalm. ...	rare, hyperparasite ?
	Microterys clavellatus, Dalm. ...	rare
	Tetrastichus rosellae, DeG. ...	abundant
	Tetrastichus inunctus, Nees ...	rare, hyperparasite
	Tetrastichus flavovarius, Nees ...	?
	Platygaster sp.	abundant
Rhabdophaga saliciperda Duf. (Diptera, Cecidomyiidae).	*Eurytoma saliciperdae*, Mayr ...	abundant
	Tridymus salicis, Nees	rare
	Microterys clavellatus, Dalm. ...	rare
	Pleurotropis sp.	?
	Calliceras sp.	?
	Conostigmus sp.	?
Euura atra Jur. (Hymenoptera, Tenthredinidae).	*Eurytoma salicis*, Thoms. ...	abundant
	Tridymus salicis, Nees	rare, hyperparasite ?
	Tetrastichus flavovarius, Nees ...	rare, hyperparasite
	Tetrastichus ? *acuminatus*, Ratz.	rare, hyperparasite

Superfamily ICHNEUMONOIDEA.

Family Ichneumonidae.

Angitia vestigialis, Ratz.

This species appears to be a well known endoparasite of *Pontania proxima*, Lep., and is recorded by Carleton (1937) as emerging in large numbers from this host. A single female emerged on 28th August 1936, from a gall of *P. proxima* on a leaf of bat willow collected at Writtle, Essex, on 15th August 1936 (Callan, 1939).

Exochus sp.

Exochus is recorded as a parasite of various Lepidoptera. A single male emerged on 8th August 1936, from a gall of *Euura atra*, Jur., on a shoot of bat willow collected at Earl's Colne, Essex, on 20th July 1936. It is improbable that *Exochus* sp. was a parasite of *E. atra*. A more likely explanation is that the gall was one of the previous year within which an undetermined Lepidopterous larva had taken refuge, and that this was parasitized by *Exochus* sp.

Meniscus frontalis, Desv.

Meniscus is recorded as a parasite of Aegeriidae and other Lepidoptera. Three males and six females emerged from 10th June to 14th July 1936, from a number of old stumps of *S. viminalis* collected at Batford, near Harpenden, Herts. Specimens of *Aegeria formicaeformis*, Esp., were also obtained from this material, and it is extremely probable that *M. frontalis* was a parasite of this species (Callan, 1940).

Sagaritis sp.

A single male emerged on 13th June 1936, from an undetermined Lepidopterous larva found feeding on the leaves of bat willow on 14th May 1936, at Ulting, Essex.

Thersilochus ? rufiventris, Brisch.

Thersilochus appears to be a parasite of various Coleoptera. On 15th June 1936, a number of males were observed assembling in large numbers around a few females, which were ovipositing in the galls of *Pontania proxima*, Lep., on the leaves of bat willows at Writtle, Essex. A number of these galls were collected at a later date, from which specimens of *P. proxima* emerged on 15th, 21st and 22nd August 1936, but no specimens of *T. rufiventris* were obtained. It is probable, but by no means certain, that *T. rufiventris* was a parasite of *P. proxima* (Callan, 1939).

The weevil, *Balaninus salicivorus*, Payk., lays its eggs in the galls of *P. proxima*, in which the larvae feed. This weevil was obtained in some numbers from this locality and it now seems more likely that *T. rufiventris* was a parasite of this species and not of *P. proxima*.

Family BRACONIDAE.

Dacnusa albipes, Hal.

Dacnusa appears to be a very specialized genus limited for host almost entirely to leaf-mining Diptera, especially AGROMYZIDAE. Two females were bred from Dipterous mines in leaves of bat willows collected at Harold Wood, Essex, on 21st July 1936. They emerged on 1st August 1936. The host was almost certainly *Phytomyza tridentata*, Lw. Nixon (1937) records that Mr. A. H. Hamm has bred this species from *P. tridentata* on *S. caprea* and on black poplar in Oxfordshire.

Rhogas irregularis, Nees.

A single female emerged on 20th June 1936, from some old stumps of *S. viminalis* collected at Batford, near Harpenden, Herts. Specimens of *Aegeria formicaeformis*, Esp., were also obtained from this material, and it is extremely probable that *R. irregularis* was a parasite of this species (Callan, 1940).

Trioxys aceris, Hal.

Trioxys is a well known Aphid parasite. A single specimen was obtained from a shoot of bat willow from Cambridge, Cambs., emerging in May 1937. Although the shoot was infested by *Rhabdophaga* sp. it is probable that this was not the host, but that the parasite emerged from an Aphid on the shoot.

Superfamily CHALCIDOIDEA.

Family TORYMIDAE.

Torymus tipulariarum, Zett.

Hoffmeyer (1930) records this species from galls of *Rhabdophaga salicis*, Schrk., *R. rosaria*, L., and *R. clavifex*, Kieff., on *Salix*. Two males of this species emerged on 6th June 1936, and one female on 10th June 1936, from *R. rosaria* galls on bat willow from Writtle, Essex. Two females were obtained in 1937 from *R. rosaria* galls on bat willow, one emerging on 30th June from galls from the above locality and the other on 6th June from galls collected at Lt. Wratting, Suffolk. A single female was bred in June 1937 from *R. salicis* galls on *S. caprea* from Pickmere, Cheshire. These galls produced two other parasites, *Tridymus salicis*, Nees, and a *Platygaster* sp., as well as *R. salicis*.

Torymus pulchellus, Thoms.

Hoffmeyer (1930) records this species from Cecidomyiid galls on *Salix*. Sixteen females in all were bred from red bud galls of *Rhabdophaga* sp. on bat willows. In 1936 three from Ulting, Essex, emerged on 19th, 20th and 23rd June, two from Chelmsford, Essex, on 19th June and one from the same locality on 30th June, and three from Roxwell, Essex, on 21st June, 1st and 2nd July. In 1937 seven from Cambridge, Cambs., emerged on 10th, 11th, 15th, 18th (2), 19th and 21st June, the emergence not starting until 16 days after that of *Rhabdophaga* sp. was complete (see fig. 1).

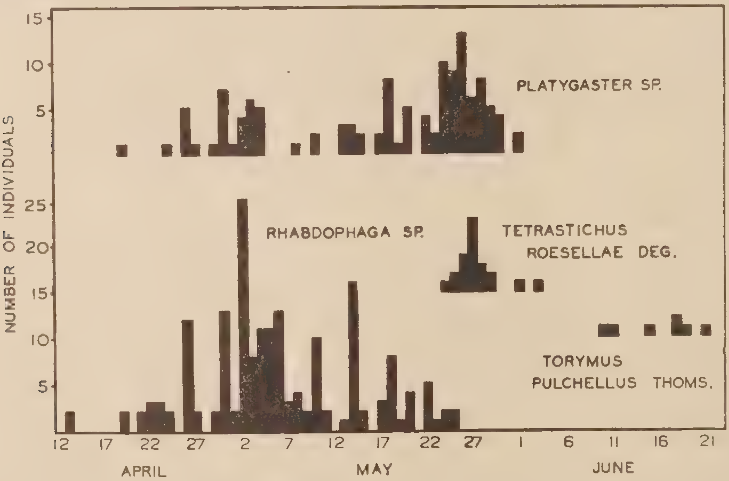

Fig. 1. Histograms showing emergence of the Gall-Midge, *Rhabdophaga* sp., and its parasites, *Torymus pulchellus*, Thoms., *Tetrastichus roesellae*, DeG., and *Platygaster* sp., at Cambridge in 1937.

Family EURYTOMIDAE.

Eurytoma saliciperdae, Mayr.

Mayr (1878) records this species from galls of *Rhabdophaga saliciperda*, Duf., on *Salix*. Barnes (1935) records it from *R. saliciperda* on bat willow and on *S. fragilis*. *E. saliciperdae* was bred from large woody galls of *R. saliciperda* on the branches of bat willow and *S. fragilis*. In all 13 males and 11 females were obtained. The species emerged from a number of galls on bat willow from Writtle, Essex, from 20th to 26th June 1936, and from a single gall on *S. fragilis* from Batford, near Harpenden, Herts., in June 1937. The galls from Writtle also produced *Pleurotropis* sp. and *Conostigmus* sp., the latter a doubtful parasite of *R. saliciperda*, and that from Batford produced three other parasites, *Tridymus salicis*, Nees, *Microterys clavellatus*, Dalm., and *Calliceras* sp.

Eurytoma salicis, Thoms.

Mayr (1878) records this species from galls of *Cryptocampus medullarius*, Hart. *Euura pentandrae*, Cam.) on *Salix*. Nielsen (1906), in giving an account of *C. angustus*, Htg. (*E. atra*, Jur.) from galls on willows, records *Eurytoma* sp. as a parasite in Denmark. This is almost certainly *E. salicis*. He makes the interesting observation that the *Eurytoma* larva is usually not fully grown after it has completely destroyed its host, and then begins to feed on the pith of the willow shoot in the same way as the host larva. It is well known that some parasitic larvae supplement their animal food with a vegetable diet, and this appears to be a good example of this habit. Such observations as have been made in the present study strongly support this conclusion. In this connexion it is interesting to note that the genus *Eurytoma* exhibits a very wide diversity of habits, ranging from a completely zoophagous diet to one entirely phytophagous. Many of the parasitic species attack a wide range of hosts, while others are specific. The phytophagous species include a number of pests which destroy the seeds of various plants.

E. salicis was bred from galls of *Euura atra*, Jur., on bat willow from Essex, Cambridgeshire and Suffolk. In all, 35 males and 26 females were obtained. A single gall usually yielded no more than one parasite, but occasionally a number of individuals were bred. Thus one individual was obtained thirty-seven times, two four times, three twice, and four and six once each, from a single gall. From localities in Cambridgeshire the rate of parasitism was 19·8 per cent. In Essex the rate of parasitism was not calculated, but appeared to be rather higher. In 1936 parasites emerged from 8th May to 8th July with a maximum emergence about the middle of June. In 1937, parasites emerged only from 1st to 22nd June, with a maximum emergence about 7th June. The emergence of *Eurytoma* did not start until that of *Euura* was for all practical purposes complete, the maximum emergence of the parasite taking place more than a month (37 days) after that of its host (see fig. 2).

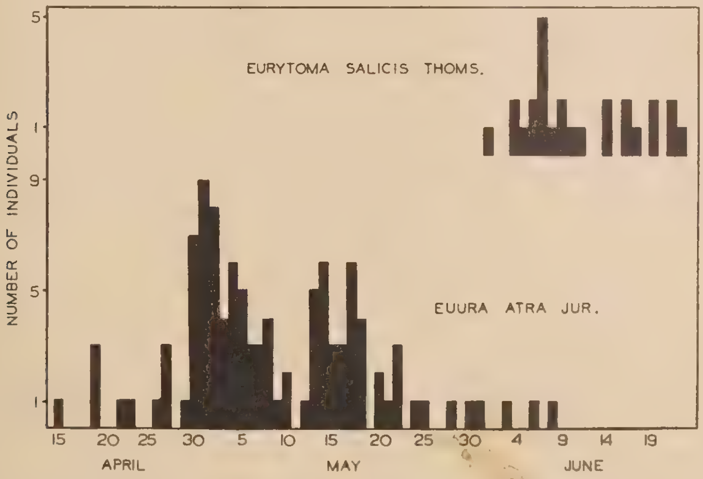

Fig. 2. Histograms showing emergence of the Sawfly, *Euura atra*, Jur., and its parasite, *Eurytoma salicis*, Thoms., at Cambridge in 1937.

Family PTEROMALIDAE.

Tridymus salicis, Nees.

Tridymus has been recorded as attacking various CECIDOMYIIDAE. Barnes (1935) records *Tridymus salicis*, Nees, as a parasite of *Rhabdophaga triandraperda*, Barnes, and *R. saliciperda*, Duf., on *Salix triandra* and *S. fragilis* respectively.

A single female was bred in June 1937 from a *R. saliciperda* gall on a branch of *S. fragilis* from Batford, near Harpenden, Herts. Three males and three females were bred in June 1937 from galls of *R. salicis*, Schrk., on *S. caprea* from Pickmere, Cheshire. Two males and one female emerged from 2nd to 12th June 1937, from galls of *Euura atra*, Jur., on bat willow from Cambridge. Although no observations were made of the parasites actually feeding on larvae of *E. atra*, this may have been the host species, which would be the first record of *T. salicis* as a parasite of TENTHREDINIDAE. On the other hand it may have been acting as a hyperparasite of *E. atra* through *Eurytoma salicis*, Thoms.

Eutelus ? semiclavatus, Ratz.

A larva of this species was found feeding externally on a *Euura* larva at Grantchester, Cambs. The host larva was almost certainly that of *E. venusta*, Zad., being found within a gall formed from the enlarged petiole of a leaf of *S. fragilis*. The parasite larva when first observed was only partly grown, and the *Euura* larva was not yet dead. Later the host larva was killed and the parasite continued to feed upon it until the body contents were consumed. When fully fed the parasite pupated and emerged as a female on 26th May 1937.

Family EUPELMIDAE.

Eupelmus urozonus, Dalm.

This ubiquitous species is recorded from a very wide range of hosts as both a parasite and a hyperparasite. The writer has previously bred it from galls of *Rhodites rosae*, L., on rose, 183 galls out of 815 collected yielding the parasite, and 93 males and 372 females being obtained. In these galls *E. urozonus* not only attacks *R. rosae*, but also the inquiline Cynipid, *Periclistus brandti*, Ratz. It also acts as a hyperparasite of both these species.

A fully fed larva of *E. urozonus* was found within a shoot of bat willow at Rayne, Essex, on 4th May 1936. It was in the same position as that typically occupied by *Rhabdophaga* sp. The larva pupated and gave rise to a female on 25th May 1936. It is probable either that the host was *Rhabdophaga* sp., or that *E. urozonus* was acting as a hyperparasite of this species through one of its more abundant parasites, such as *Torymus pulchellus*, Thoms., or *Platygaster* sp.

Family ENCYRTIDAE.

Microterys clavellatus, Dalm.

The majority of records refer to this species as a Coccid parasite. One female emerged on 15th May 1936, from a shoot of bat willow from Rayne, Essex, and three females on 16th July 1936, from a shoot of bat willow from Writtle, Essex. These were probably parasites of *Rhabdophaga* sp. Three females emerged on 22nd May 1937, from a single larva of *Rhabdophaga* sp. removed from a shoot of bat willow from Cambridge. Three females emerged on 25th May 1937, from a single larva of *R. saliciperda* removed from a branch of *S. fragilis* from Batford, near Harpenden, Herts.

These appear to be the first records of *M. clavellatus* as a parasite of CECIDOMYIIDAE.

Family EULOPHIDAE.

Pleurotropis sp.

Pleurotropis is a parasite with a wide host range and has frequently been recorded as attacking CECIDOMYIIDAE. Barnes (1935) records *Pleurotropis ? caenus*, Walk., from either *Rhabdophaga purpureaperda*, Barnes, or *R. justini*, Barnes, on *Salix purpurea.*

A single specimen emerged on 20th June 1936, from a gall of *R. saliciperda*, Duf., on a branch of bat willow from Writtle, Essex. Although it is not certain it is probable that the host was *R. saliciperda.*

√ **Tetrastichus roesellae,** DeG.

This species is a well known parasite of CECIDOMYIIDAE and a few other insects. Barnes (1935) records it from *Rhabdophaga triandraperda*, Barnes, on *S. triandra* and from either *R. purpureaperda*, Barnes, or *R. justini*, Barnes, on *S. purpurea.*

A single male emerged on 20th May 1936, from a gall of *R. rosaria*, L., on bat willow from Ulting, Essex. A female was obtained on 30th June 1937, from a *R. rosaria* gall on bat willow from Writtle, Essex, from which *Torymus tipulariarum*, Zett., also emerged. From 24th May to 3rd June 1937, 5 males and 17 females emerged from galls of *Rhabdophaga* sp. on bat willow from Cambridge. *Platygaster* sp. was also obtained from these galls (see fig. 1).

Tetrastichus inunctus, Nees.

This species is recorded from a fairly wide range of hosts. The writer has previously bred what is believed to be this species as a parasite of *Periclistus caninae*, Htg., an inquiline Cynipid in the galls of *Rhodites eglanteriae*, Htg., on rose. Barnes (1934) records it from galls of *Rhabdophaga heterobia*, H. Lw., on *S. triandra.*

A larva of this species was found feeding externally on what appeared to be another Chalcidoid larva within a bat willow shoot at Roxwell, Essex. It was in the same position as that typically occupied by *Rhabdophaga* sp. The larva when first observed was only partly grown ; it pupated when fully fed and emerged as an adult on 23rd June 1936. It is most probable that *Rhabdophaga* sp. was the host, *T. inunctus* acting as a hyperparasite of this species through one of its parasites. A single individual of *T. inunctus* emerged on 14th August 1936, from a gall of *Rhabdophaga* sp. on bat willow at Cambridge.

Tetrastichus flavovarius, Nees.

This species is a well known parasite of CECIDOMYIIDAE and a few other insects. Barnes (1935) records it as a parasite of *Rhabdophaga triandraperda*, Barnes, and *R. saliciperda*, Duf., on *S. triandra* and bat willow respectively.

A single individual emerged on 1st July 1936, from a gall of *Rhabdophaga* sp. on bat willow from Roxwell, Essex. In 1937 one individual emerged from 2nd to 12th June from a gall of *Euura atra*, Jur., on bat willow from Cambridge, and another on 3rd June from a similar gall on bat willow from Ickleton, Cambs. It seems probable that in this case *T. flavovarius* was acting as a hyperparasite of *E. atra* through *Eurytoma salicis*, Thoms.

√ **Tetrastichus ? acuminatus,** Ratz.

Two females emerged on 4th and 6th July 1937, from galls of *Euura atra*, Jur., on bat willow from Cambridge. *Eurytoma salicis*, Thoms., was also obtained from similar galls collected at the same time. It seems probable that *T. acuminatus* was acting as a hyperparasite of *E. atra* through *E. salicis.*

Family MYMARIDAE.

Polynema sp.

Polynema appears to be a well known egg parasite, attacking especially the eggs of Hemiptera. A single specimen was bred from a woody shoot of bat willow collected at Rayne, Essex, on 21st May 1936, and emerging on 15th June 1936. It was thought that this had emerged from one of a number of COCCIDAE infesting the shoot, but it is more probable that it was parasitizing an egg inserted in the bark of the shoot, probably that of a Capsid.

Superfamily PROCTOTRUPOIDEA.

Family CALLICERATIDAE.

Calliceras sp.

Calliceras is a parasite and hyperparasite of wide host range, including various Diptera. It has been recorded as attacking CECIDOMYIIDAE. A single specimen was obtained from a gall of *Rhabdophaga saliciperda*, Duf., on a branch of *S. fragilis* collected at Batford, near Harpenden, Herts., on 31st May 1937, and emerging on 7th June 1937. Although it is not certain, it is probable that the host was *R. saliciperda.*

Conostigmus sp.

Conostigmus is a parasite of various Diptera. It has apparently not been recorded as attacking CECIDOMYIIDAE. A single specimen was obtained from a gall of *Rhabdophaga saliciperda*, Duf., on a branch of bat willow collected at Writtle, Essex, on 17th June 1936, and emerging on 26th June 1936. Although it is not certain, it is possible that the host was *R. saliciperda.*

Family SCELIONIDAE.

Telenomus punctatissimus, Mayr.

Telenomus is a well-known egg parasite, attacking a wide range of hosts, especially the eggs of Lepidoptera and Hemiptera. A number of specimens were bred from the eggs of *Phalera bucephala*, L. (buff-tip moth) on leaves of bat willow from Chelmsford, Essex. They emerged on 7th August 1936.

Platygaster sp. (*a*).

Barnes (1935) records *Platygaster cecidomyiae*, Ratz., as a parasite of *Rhabdophaga saliciperda*, Duf., on *S. fragilis*. He also records *Platygaster* sp. (? *philinna*, Walk.) as a parasite of *R. triandraperda*, Barnes, on *S. triandra* and of either *R. purpureaperda*, Barnes, or *R. justini*, Barnes, on *S. purpurea.*

Four females of *Platygaster* sp. were obtained in 1936 from galls of *Rhabdophaga* sp. on bat willow from Rayne, Ulting and Lt. Waltham, Essex, emerging on 15th and 20th May and 4th June.

Platygaster sp. was bred in 1937 from galls of *Rhabdophaga* sp. on bat willow from Cambridge. A single gall usually yielded only one parasite but occasionally a number of individuals were obtained. In all, 63 males and 59 females were obtained. The rate of parasitism was 40·5 per cent. Emergence of parasites occurred from 19th April to 1st June, coinciding approximately with that of *Rhabdophaga* sp., although the maximum emergence of *Platygaster* took place 24 days later than that of its host (see fig. 1).

Platygaster sp. (*b*).

One male and six females were bred in June 1937 from galls of *Rhabdophaga salicis*, Schrk., on *S. caprea* from Pickmere, Cheshire. *Platygaster* sp. was probably a parasite of *R. salicis*, but may have been acting as a hyperparasite of this species through *Tridymus salicis*, Nees, which was also bred from these galls.

Platygaster sp. (*c*).

A single female emerged on 17th May 1936, from a gall formed from an enlarged bud of *S. caprea* from Bicknacre, Essex. The host was almost certainly a Cecidomyiid, probably a *Rhabdophaga* sp.

Summary.

1. Eight Ichneumonoidea, fourteen Chalcidoidea and six Proctotrupoidea are recorded as parasites of willow insects.

2. The majority of records are of parasites bred from insects inhabiting the wood of the cricket bat willow, *Salix alba* var. *caerulea*, Smith, the more important being *Torymus pulchellus*, Thoms., *Tridymus salicis*, Nees, *Eupelmus urozonus*, Dalm., *Microterys clavellatus*, Dalm., *Tetrastichus roesellae*, DeG., *Tetrastichus inunctus*, Nees, *Tetrastichus flavovarius*, Nees, *Tetrastichus* ? *acuminatus*, Ratz., and *Platygaster* sp.

3. *Microterys clavellatus* is recorded for the first time as a parasite of Cecidomyiidae.

4. Evidence is given for the separation of the gall-midges, *Rhabdophaga* sp. and *R. saliciperda*, Duf., as distinct species based both on structural differences and on a study of their parasites, for the three parasites found most commonly attacking *Rhabdophaga* sp. were never bred from *R. saliciperda*, and the most common species parasitizing *R. saliciperda* was never obtained from *Rhabdophaga* sp.

5. It is confirmed that *Eurytoma salicis*, Thoms., supplements its animal diet with vegetable food.

6. The rate of parasitism of *Euura atra*, Jur., by *Eurytoma salicis* is given as 19·8 per cent., and that of *Rhabdophaga* sp. by *Platygaster* sp. as 40·5 per cent.

7. Histograms are given of *Rhabdophaga* sp. and its parasites, *Torymus pulchellus*, Thoms., *Tetrastichus roesellae*, DeG., and *Platygaster* sp., the emergence of *Platygaster* sp. coinciding approximately with that of its host.

8. Histograms are given of *Euura atra*, Jur., and its parasite, *Eurytoma salicis*, Thoms., the emergence of which did not start until that of its host was practically complete.

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A STUDY OF THE VARIATION OF SIZE WITHIN TWO SPECIES OF APHIDES.

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1. Introduction.

For purposes of identifying certain closely allied species of aphides, where there are no obvious specific characters, systematists sometimes have recourse to the ratios between the lengths of different organs, *e.g.*, the length of the third segment of the antenna to that of the cornicle on the same side. The necessary qualifications for the choice of such characters should be a high degree of correlation between them and they should be parts of the Aphid that are not usually damaged, the apical segment of the antenna, for instance, being seldom used because it is so easily broken. Most aphides suffer some slight injury during their lifetime, and further damage is not infrequent during the process of preparing mounts. This explains the unequal frequencies in the following calculations.

No one appears to have studied in detail the variation between individuals of the same species. When characters have been measured, small numbers of insects have been used, in general varying from one to twelve. There being insufficient data for a statistical analysis, only the actual measurements have been quoted.

During the past three years at East Malling the *Rubus* aphides have received a detailed study by one of the present writers. In the course of the work as accurate data as possible were obtained on the various morphological characters in general use for the identification of species. These data have now been used to find the variation associated with samples of different sizes, and also to determine whether this variation is equally distributed about the mean.

Two species with different habits have been examined :—

Macrosiphum rubiellum, Theobald, is a blackberry Aphid. Eggs laid on blackberry in the autumn hatch in February or early March. Two apterous viviparous generations and one alate generation (migrant) are produced on blackberry, the winged forms flying off to *Poa annua*, L., on maturing in early June. Another alate viviparous generation (sexuparae) appears on grass in October and returns to blackberry to deposit young which develop into oviparous females. The males fly back from grass one generation after the sexuparae.

Aphis idaei, van der Goot, lives on raspberry all the year. Hatching rather later than *rubiellum* it produces winged forms in June, but instead of migrating these disperse among the winter host-plants. Oviparous females and wingless males are the progeny of apterous viviparous females, and first appear at the beginning of October.

In both species the apterous viviparous females referred to are the adults of the second generation after hatching.

2. Technique and Procedure.

Origin of Material.

All the aphides were collected in the field during observations on the biology of the species ; *M. rubiellum* from cultivated blackberry and *A. idaei* from raspberry. During the first three generations of both species the aphides live in colonies. To avoid using clonal material (*i.e.* a family asexually produced from a single parent) samples of the apterous viviparae and alate viviparae were taken from numerous colonies. For all the other forms only solitary specimens could be found and since these were collected from many parts of the plantation there should be no trace of clonal origin.

Preservation and Preparation of Mounts.

All specimens were preserved in 70 per cent. alcohol for one or two weeks before mounting. To remove the body-contents five to ten minutes in boiling 10 per cent. caustic potash was sufficient. This was followed by two washes each of five minutes and a final wash of fifteen minutes in distilled water. Specimens were then mounted directly on to flat slides in Berlese's fluid.

Measurements.

All measurements were made with a monocular microscope using a constant magnification of 310 times. Lengths were recorded in units as measured on a graduated scale in the eyepiece. These figures were used in computing, the final results being converted to microns.

Scheme of the Statistical Work.

Three investigations were undertaken :—

(1) The correlations between the lengths of organs, to discover whether the practice of using ratios of lengths of parts as a means of classification made best use of the numerical data.

(2) The extent of variation, in order that limits might be assigned to the sizes of organs, beyond which only a known proportion of specimens would be expected.

(3) The manner in which the measurements varied about their mean. This was necessary, since if the various measurements departed materially from the so-called " normal " distribution about the mean, upon which most statistical theory is based, modifications in method might have to be adopted.

3. Correlations.

Tables I and II set out the correlation coefficients, r, between organs, and the number of pairs of observations in the samples from which they were calculated. The coefficient is zero if there is no association between the lengths of the two organs, and, if there be an association, it is positive or negative according as an increase in one is associated with an increase or decrease in the other. The extreme limits of r are ± 1.

Table I shows that the correlations between the *same* organ on different sides of the body are always positive and usually high. This is especially so with *M. rubiellum.* In any one form of either species the correlation of right and left sides is highest for the cornicles, somewhat lower for any of the antennal segments, and much lower and less consistent for the hind tarsi. The several segments of the antennae give closely concordant results. With the exception of the hind tarsi of the alate viviparae of *A. idaei* none of the results could have arisen by chance from an uncorrelated population more often than once in a hundred times ; and excluding also the hind tarsi of the sexuparae and oviparae of *M. rubiellum* they are significant at the 1 in 1,000 level.

TABLE I.

Correlations between the lengths of the same organs on different sides of the body.

Macrosiphum rubiellum.	Apt. viviparae		Alate viviparae.		Sexuparae		Oviparae		Males	
	n	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*
Antenna III	36	**·82**	32	**·88**	32	**·96**	33	**·93**	32	**·90**
,, IV	36	**·90**	29	**·91**	32	**·93**	33	**·88**	31	**·86**
,, V	35	**·90**	27	**·85**	32	**·90**	33	**·91**	30	**·86**
Cornicle	35	**·97**	28	**·93**	31	**·97**	34	**·94**	31	**·96**
Hind tarsus	31	**·66**	19	**·81**	17	·58	28	**·56**	23	**·85**
Aphis idaei.										
Antenna III	38	**·59**	36	**·71**	—	—	29	**·72**	35	**·79**
,, IV	38	**·65**	36	**·66**	—	—	27	**·71**	36	**·66**
,, V	38	**·58**	36	**·64**	—	—	—	—	—	—
Cornicle	36	**·95**	33	**·93**	—	—	36	**·85**	36	**·80**
Hind tarsus	29	**·66**	31	·40	—	—	22	**·65**	26	**·82**

Figures in bold type are significant at 1 in 100.

TABLE II.

Correlations between the lengths of different organs on the right side of the body.

	Apt. viviparae		Alate viviparae		Sexuparae		Oviparae		Males	
Macrosiphum rubiellum.	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*
Antenna III and IV ...	36	**·64**	32	**·61**	32	**·66**	33	**·72**	31	**·74**
,, III and V... ...	35	·39	32	**·67**	32	**·69**	33	**·76**	30	**·72**
,, III and sensoria III	36	·18	34	·24	32	·26	—	—	32	·31
,, III and cornicle ...	35	**·48**	27	**·52**	31	·44	33	**·51**	32	·31
,, III and cauda ...	36	**·63**	33	·40	32	·30	33	**·46**	30	·19
,, III and hind tarsus	34	·34	22	**·55**	22	·13	30	·30	26	·05
,, IV and V	35	**·67**	32	**·83**	32	**·85**	33	**·83**	30	**·75**
,, IV and sensoria IV	—	—	—	—	—	—	—	—	31	·40
,, IV and cornicle ...	35	·41	25	**·70**	31	·43	33	**·61**	31	·36
,, IV and cauda ...	36	**·47**	31	·31	32	·36	33	·39	30	·39
,, V and sensoria V	—	—	—	—	—	—	—	—	30	·37
,, V and cornicle ...	34	·39	25	**·51**	31	·34	33	**·45**	30	·20
,, V and cauda ...	35	·25	31	·36	32	·29	33	·39	29	·26
Cornicle and cauda ...	35	**·77**	29	**·54**	31	**·76**	34	**·70**	30	**·71**
,, and hind tarsus ...	33	·37	21	**·61**	21	**·51**	30	·33	26	·15
Cauda and hind tarsus ...	34	·32	24	**·66**	22	**·64**	30	·45	25	·23
Aphis idaei.										
Antenna III and IV ...	38	**·49**	36	·18	—	—	34	**·66**	35	**·63**
,, III and sensoria III	—	—	36	·21	—	—	—	—	35	·17
,, III and cornicle ...	37	·01	34	·38	—	—	34	**·50**	35	**·59**
,, III and cauda ...	38	·19	36	·15	—	—	26	**·59**	25	·39
,, III and hind tarsus	33	·19	34	·22	—	—	24	—·29	28	·19
,, IV and cornicle ...	37	·04	34	·38	—	—	33	·43	36	**·65**
,, IV and cauda ...	38	·16	36	**·42**	—	—	26	**·50**	26	·30
Cornicle and cauda... ...	37	**·78**	34	·14	—	—	28	**·73**	26	**·54**
,, and hind tarsus ...	32	·28	32	—·03	—	—	26	—·05	29	—·06
Cauda and hind tarsus ...	33	**·50**	34	**·47**	—	—	19	—·08	21	—·19

Figures in bold type are significant at 1 in 100.

From this high association between the sides it follows that a measurement of an organ on one side of the body is little less reliable than the mean of both sides, for if the two sides have each a standard error, $S\text{–}E$, and a correlation coefficient, r, the standard error of their mean is $S\text{–}E\sqrt{\frac{1+r}{2}}$, or almost the same as for one side alone.

The correlations between *different* organs on the right side are shown in Table II, and are not as large as those already considered. In *M. rubiellum* the highest correlations are between any two segments of the antenna, and between the cornicle and cauda, all being significant at the 1 in 100 level with one exception, namely, antennae III and V of the apterous viviparae. The cornicles and cauda both show approximately the same degree of correlation with any segment of the antenna. The hind tarsi give consistently low correlations with other organs except in one form, the alate viviparae, which had already shown an abnormally high correlation between the two sides. The lengths of the segments of the antennae are insignificantly correlated with the numbers of sensory organs upon them.

It will be seen in *M. rubiellum* that the sexuparae and males, which develop on *Poa annua*, L., give a few very low correlations. These forms are produced between September and November when the grasses are dying down, and it is possibly the condition of the food supply which makes these forms different from those found only on *Rubus.*

In *A. idaei* the third segment of the antenna correlates well with the fourth, and the cornicle with the cauda, though for both combinations the alate viviparae provide exceptions. The hind tarsi fail to correlate with anything except the cauda and then only in the apterous and alate viviparae.

Forms that tend to give the lowest correlations are the apterous and alate viviparae in *A. idaei* and sexuparae and males in *M. rubiellum.*

On the evidence of these two species alone it is difficult to recommend any two organs, the ratio of which would aid in classification when other characters fail. The lengths of antenna III and IV, also the cornicle and cauda, give the most consistently high correlations, but even these fail in certain forms. At present systematists usually choose the cornicle and antenna III, and until further species are examined there is insufficient evidence to better this choice.

4. The Extent of Variation.

The information necessary to determine limits of variation is given by Tables III and IV, which show in the second and third columns under each form the mean lengths and standard errors in microns, and in the first column the number of specimens upon which these estimates are based. With the exception of the cauda each organ is present on both right and left sides of the aphid, but only the right side has been considered. It has already been shown in the preceding section that this procedure is a reasonable one.

Suppose a sample of M aphides has been collected, and it is desired to test whether it differs sufficiently, in some numerical value, from a sample of N already described, to be considered another species. Given information such as in Tables III and IV this can be done by the use of a criterion known as t, which is equal to the difference of the two sample means divided by its standard error, *i.e.* $S\text{–}E\sqrt{\frac{1}{M}+\frac{1}{N}}$, where $S\text{–}E$ is the standard error of an individual. The degrees of freedom are one less than the number of readings from which the standard error has been calculated, viz. (N–1) (Yule & Kendall, 1937). This quantity, t, has been tabulated (Fisher & Yates, 1935) and thus it is possible to determine the frequency by which any given

TABLE III.

Mean Values and Standard Errors in Microns—M. rubiellum.

	Apt. viviparae			Alate viviparae			Sexuparae			Oviparae			Males		
	N	Mean	*S–E*	*N*	Mean	*S–E*	*N*	Mean	*S–E*	*N*	Mean	*S–E*	*N*	Mean	*S–E*
Length of :—															
Antenna III	36	700	38	34	688	38	32	683	62	33	449	31	32	776	50
,, IV	36	497	32	32	531	47	32	463	47	33	297	28	31	543	40
,, V	35	430	33	32	467	44	32	413	36	33	285	21	30	475	35
Cornicle	35	826	55	29	698	50	31	553	61	34	508	34	32	501	42
Cauda	36	367	27	35	302	17	32	236	23	34	217	16	30	159	17
Hind tarsus	34	165	4	24	156	5	22	143	5	30	134	4	26	137	7
Number of :—															
Sensoria III	—	—	—	35	13·6	1·8	32	16·0	2·2	—	—	—	32	54·3	5·6
,, IV	—	—	—	—	—	—	—	—	—	—	—	—	31	16·0	3·2
,, V	—	—	—	—	—	—	—	—	—	—	—	—	30	14·5	2·8

TABLE IV.

Mean Values and Standard Errors in Microns—A. idaei.

	Apt. viviparae			Alate viviparae			Oviparae			Males		
	N	Mean	*S-E*	*N*	Mean	*S-E*	*N*	Mean	*S-E*	*N*	Mean	*S-E*
Length of :—												
Antenna III	38	233	17	36	229	14	34	172	13	35	174	15
Antenna IV	38	152	14	36	162	12	33	80	8	36	73	9
Antenna (flagellum)	37	230	16	36	249	14	26	184	15	33	152	16
Cornicle	37	406	44	34	259	17	35	169	12	36	140	13
Cauda	38	136	9	36	103	7	29	73	5	26	45	4
Hind tarsus	33	106	6	34	102	4	26	64	3	29	54	5
Number of :—												
Sensoria III	—	—	—	36	4·6	·9	—	—	—	36	8·1	1·4
Sensoria IV	—	—	—	—	—	—	—	—	—	36	2·8	·7

value of it will be exceeded. If there be more than 20 degrees of freedom, a condition satisfied throughout this paper, t exceeds 1·0 about once in three times, 2·0 about once in 20 times and 3·0 about once in 300 times; though for fewer degrees of freedom these approximations do not hold.

To take a numerical example, suppose a sample of five aphides are believed to be apterous viviparae of *M. rubiellum*, and measurements of the cauda give a mean length of 341 μ. Table III gives 367 μ as the mean length of a sample of 36, a difference of 26μ. The denominator of t, $27\sqrt{\frac{1}{5}+\frac{1}{36}}\mu$, equals 12·9μ, and t is $\frac{26}{12{\cdot}9}$ or 2·02. For (36–1) degrees of freedom the value of t exceeded by chance once in 20 times is 2·03, so the difference between the sample means is scarcely significant, being small enough to arise frequently by chance.

If, however, a larger sample, say of twelve specimens, gave the same mean length of cauda, the difference would remain 26μ, but the new divisor would be $27\sqrt{\frac{1}{12}+\frac{1}{36}}\mu$ or 9·0μ, making t equal to 2·89, a value exceeded by chance less than once in 100 times. Thus the significance becomes greater as the size of the newly collected sample increases.

The usual assumption has been made that the distribution is normal; and this will be justified in section 5.

From Tables III and IV it will be noticed that most of the standard errors are about 7 per cent. of the means, though they are consistently lower for the hind tarsi of all forms in both species except the males of *A. idaei*. All organs of the sexuparae of *M. rubiellum* have standard errors of about 10 per cent. of the means. For purposes of classification the most useful organs to measure are those that are highly correlated with the greatest number of parts. Thus the hind tarsus would be of little use, although it has such a low standard error. The other organs have standard errors which agree very closely, and so the choice must depend upon the correlations. These, however, do not give any clear indication as to which will be the most useful.

5. The Form of Variation.

An assumption has been made throughout that the distribution of the measurements is of the normal or Gaussian type. This is the usual procedure, but its validity in the present work has been investigated.

The manner in which a series of observations are distributed can be well described by the methods used by Karl Pearson (1930) who defined distribution by three statistics, β_1 the amount of asymmetry, β_2 the kurtosis and *sk* the skewness. β_1 measures the departure from symmetry by comparing the weights of the two tails, β_2 measures the relationship of the weight of the tails with that of the peak. In the normal curve, which is symmetrical about the mean, $\beta_1=0$ and $\beta_2=3$. Distributions with $\beta_2>3$ have narrower peaks and larger tails than normal, but when $\beta_2<3$ the reverse occurs. The skewness, *sk*, is the distance of the most likely value from the mean, expressed in terms of the standard deviation, and is without sign, though in this paper the convention has been adopted of giving it the sign of the heavier tail. This definition of skewness has been extended also to describe U-shaped distributions, where the distance of the mean from the least likely value has been used, with a negative sign if the minimum is below the mean.

Karl Pearson (1930) also worked out a system of curves corresponding to possible distributions. Tables V and VI show not only the asymmetry, kurtosis and skewness of the distributions of the lengths of organs and numbers of sensoria in the two species, but also the type of Pearson curve best fitting the data.

Except with the antennae in certain forms of *M. rubiellum*, the kurtosis rarely attains the normal value of 3, which shows that the peaks of the distributions are flattened. However, departures from normality in living organisms are not uncommon, and it is therefore unnecessary to suppose that two or more species have been mixed in each collection of aphides, for the low kurtosis can be more convincingly explained by a consideration of the causes of variation. All the aphides were collected under similar conditions, and the principal source of variation therefore is probably genetical, which would give rise to differences only within definite limits. This is confirmed by the fact that the curve best fitting most of the distributions is Pearson's Type I_I, which has definite limits to both higher and lower values. The few better fitted by Types IV or VI are balanced by others of Types J_I or U_I, so it is reasonable to suppose that the populations are of Type I_I and only sampling error gives rise to any other form. On this hypothesis then, the low kurtosis is the result of finite tails, which in turn are due to the variation being mainly genetical, and not to a mixture of species.

The most consistent measures of distribution are the skewnesses, which seem to vary regularly from one form of a species to another. For example, the sexual forms of *A. idaei* have in general a more positive skewness than the viviparae. It is not possible to test such an assertion, using the common technique of the analysis of variance, because skewnesses evidently have a distribution far from normal, as is shown by the value obtained for the right cornicles of the apterous viviparae of *A. idaei*. However, the Binomial Theorem is of some use, for if there be no skewness in the population, the skewness of a sample of that population is equally likely to be positive or negative. Considering only the lengths of organs, when all forms of *A. idaei* are taken together the positive and negative skewnesses are equal in number. When, however, the different forms are separated it is found that there is a definite preponderance of positive or negative values in certain forms ; thus the apterous viviparae give nine negative and two positive skewnesses. If the sample skewnesses were independent this would happen only once in twenty-nine times when sampling from a symmetrical population, so the presumption is that the population is really negatively skew. Taking next the sexual forms, sixteen out of the twenty-two skewnesses are positive, again an event arising by chance only once in twenty-nine times, so it is probable that these populations are positively skew. The alate viviparae occupy an intermediate position.

In *M. rubiellum* it is found that while the oviparae show a significant positive skewness, the other forms taken together have a significant negative one. There is evidence also that the segments of the antennae have a more positive skew than the other organs. In both species the hind tarsi behave in an irregular manner, even the two sides often failing to agree.

It will be seen that almost all distributions are asymmetrical and flat-topped, and though few are significantly non-normal by themselves, the accumulated evidence is that the approach to normality is not good enough for assigning limits of variation by normal theory, though E. S. Pearson (1931) has shown it is adequate for the analysis of variance, and Hey (1938) that it would not seriously affect the significance of correlation coefficients.

Departures from normality can, however, be diminished by taking the mean of several observations as is shown in fig. 1, where curve N represents the normal and curve 1 the Pearson curve fitting a distribution with asymmetry equal to 0·25 and kurtosis 2·75. The limits indicated in the figure are so calculated that $2\frac{1}{2}$ per cent. of the area of the normal curve lies outside each, and it will be seen that while one limit is not reached by curve 1 the other is exceeded by more than $2\frac{1}{2}$ per cent. of the area. Curves 2 and 5 represent the distributions of means of two and five specimens respectively, and successively approach the normal, so that for the larger sample the limits calculated by normal theory are not inappropriate. Given then measurements

TABLE V.

Forms of Distribution—M. rubiellum.

	Apt. viviparae				Alate viviparae				Sexuparae				Oviparae				Males			
	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*
Length of :—																				
R. Antenna III ...	·1	4·0	IV	+ ·13	·0	3·8	IV	— ·02	·7	4·7	IV	— ·30	·2	3·0	I_{I}	+ ·34	·0	2·8	I_{I}	+ ·01
L. Antenna III ...	·5	4·5	IV	+ ·27	·1	4·0	IV	+ ·11	·0	3·5	IV	— ·07	·6	3·4	I_{I}	+ ·63	·2	2·5	I_{I}	+ ·62
R. Antenna IV ...	·0	2·5	I_{I}	+ ·14	·0	2·5	I_{I}	— ·02	·0	2·7	I_{I}	+ ·14	·8	3·9	I_{I}	+ ·55	·1	2·6	I_{I}	— ·20
L. Antenna IV ...	·2	3·3	I_{I}	+ ·24	·3	2·9	I_{I}	+ ·48	·1	2·6	I_{I}	— ·17	·0	3·2	IV	+ ·02	·1	3·4	IV	— ·10
R. Antenna V	·0	2·0	I_{I}	— ·04	·1	3·3	IV	— ·17	·2	2·5	I_{I}	— ·50	·5	3·2	I_{I}	+ ·60	·4	2·6	I_{I}	—1·19
L. Antenna V	·1	1·7	U_{I}	— ·53	·0	3·1	IV	— ·09	·0	2·7	I_{I}	— ·09	·9	3·8	I_{I}	+ ·73	·1	2·9	I_{I}	— ·13
R. Cornicle	·2	2·9	I_{I}	— ·34	·3	3·0	I_{I}	— ·34	·0	2·3	I_{I}	— ·19	·0	2·8	I_{I}	+ ·03	·0	2·2	I_{I}	— ·32
L. Cornicle	·0	2·5	I_{I}	— ·17	·3	3·3	I_{I}	— ·28	·0	2·1	I_{I}	— ·38	·1	3·0	I_{I}	+ ·21	·3	2·4	I_{I}	—1·17
Cauda	·1	3·3	IV	— ·14	1·0	5·3	IV	— ·37	·4	3·1	I_{I}	— ·57	·0	2·3	I_{I}	— ·14	·3	2·6	I_{I}	— ·70
R. Hind tarsus ...	·1	2·4	I_{I}	— ·26	·0	2·5	I_{I}	— ·20	·1	2·2	I_{I}	— ·56	·1	2·2	I_{I}	+ ·47	·0	3·1	IV	+ ·06
L. Hind tarsus ...	·3	2·4	I_{I}	— ·96	·2	2·8	I_{I}	+ ·41	·0	1·8	I_{I}	+ ·46	·1	1·7	U_{I}	+ ·67	·8	4·4	VI	— ·41
Number of :—																				
R. Sensoria III ...	—	—	—	—	·6	3·0	I_{I}	— ·99	·0	2·0	I_{I}	— ·06	—	—	—	—	·2	3·3	I_{I}	+ ·23
L. Sensoria III ...	—	—	—	—	·2	2·4	I_{I}	+ ·50	·3	2·5	I_{I}	+1·27	—	—	—	—	·0	3·2	IV	+ ·10

Where β_1 is given as ·0, additional decimal places were computed in order to determine the type and evaluate *sk*.

TABLE VI.

Forms of Distribution—A. idaei.

	Apt. viviparae				Alate viviparae				Oviparae				Males			
	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*	β_1	β_2	Type	*sk*
Length of :—																
R. Antenna III	·0	2·8	I_I	+·08	·0	2·3	I_I	+·01	·1	2·6	I_I	+·35	·0	3·1	IV	−·01
L. Antenna III	·1	2·5	I_I	−·37	·1	2·8	I_I	−·15	·0	2·7	I_I	+·02	·3	3·4	I_I	−·30
R. Antenna IV	·1	3·1	I_I	+·20	·0	2·2	I_I	−·02	·0	2·5	I_I	+·03	·1	2·2	I_I	−·51
L. Antenna IV	·4	3·1	I_I	−·55	·3	2·7	I_I	−·53	·9	3·8	I_I	+·68	·2	3·7	IV	+·17
R. Antenna (flagellum) ...	·0	2·7	I_I	−·02	·1	2·9	I_I	−·19	·0	2·7	I_I	−·14	·2	2·9	I_I	+·36
L. Antenna (flagellum) ...	·0	2·4	I_I	−·10	·0	2·4	I_I	+·10	·9	3·4	J_I	−1·41	·0	2·7	I_I	+·01
R. Cornicle	·5	2·5	J_I	−3·98	·5	3·5	I_I	−·43	·4	3·5	I_I	+·36	·3	2·9	I_I	+·40
L. Cornicle	·3	2·5	I_I	−·90	·4	3·4	I_I	−·35	·8	4·4	VI	+·41	·1	2·4	I_I	+·32
Cauda	·1	2·4	I_I	−·30	·1	2·5	I_I	+·35	·0	2·5	I_I	+·03	·1	2·1	I_I	+·54
R. Hind tarsus	·1	2·4	I_I	−·47	·3	3·5	I_I	−·30	·0	3·0	I_I	+·06	·1	2·3	I_I	+·48
L. Hind tarsus	·1	2·3	I_I	−·28	·1	2·1	I_I	+·74	·2	3·5	VI	−·17	·1	2·1	I_I	+·57
Number of :—																
R. Sensoria III	—	—	—	—	·6	2·9	I_I	+1·10	—	—	—	—	·0	2·6	I_I	−·01
L. Sensoria III	—	—	—	—	·0	2·4	I_I	+·11	—	—	—	—	·0	2·4	I_I	+·06
R. Sensoria IV	—	—	—	—	—	—	—	—	—	—	—	—	·0	2·6	I_I	−·16
L. Sensoria IV	—	—	—	—	—	—	—	—	—	—	—	—	·3	2·5	I_I	+·79

Where β_1 is given as ·0, additional decimal places were computed in order to determine the type and evaluate *sk*.

of five or more specimens it should be possible to assign limits for the variation of their mean, if the specimens belong to a known form of a known species. The low kurtosis will result in limits calculated by normal theory being slightly too wide. The tendency to vary unequally on the two sides of the mean will be important when limits have been fixed, for it will be desirable to know which is the more likely to be exceeded.

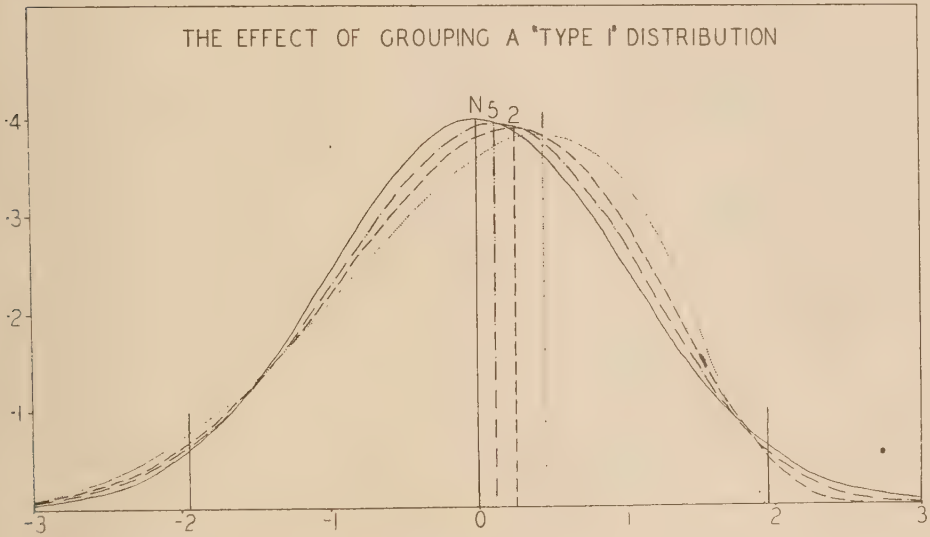

Fig. 1. Curve 1 ($\beta_2 = \cdot25$, $\beta_1=2{\cdot}75$, $sk=-\cdot442$) represents the supposed distribution of an individual. Curve 2 ($\beta_2=\cdot125$, $\beta_1=2{\cdot}875$, $sk=-\cdot225$) and Curve 5 ($\beta_1=\cdot05$, $\beta_2=2{\cdot}95$, $sk=-\cdot122$) represent the distributions of means of two and five respectively, and successively approach the Normal Curve, N. ($\beta_1=0$, $\beta_2=3$, $sk=0$.)

6. Conclusions.

In order to assign limits an approach to normality is required better than that found for the measurements of individual organs, therefore the means of samples of five or more should be taken. To detect differences with reasonable certainty larger samples would be required. The standard error in both species is of the order of 7 per cent. of the mean, though it may even reach 10 per cent. When dealing with other species it would be wise to assume that the variation is as great, in the absence of evidence to the contrary. The writers are of the opinion that this information could be used to make an accurate estimate of the chances of given specimens belonging to a certain species, where other means of classification fail. A good criterion would be to consider evidence of a new species insufficient unless the value of t, calculated by the method described, exceeds 3·0. Even this ignores possible differences between seasons and localities.

Also it would be helpful if writers in describing a new species would give not only the number and mean size of their specimens, but also the standard error of the individuals.* From this it would be possible to determine whether the specimens were chance variants of a described species. This applies, of course, only where the statistical evidence is the deciding factor.

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* Where s is the sum of the N measurements and S the sum of their squares, $S\text{–}E=\sqrt{\dfrac{NS-s^2}{N(N-1)}}$.

The correlations show that no two organs have a stable ratio in all forms, though it may be that seasonal changes, if they exist, will affect all organs similarly, and so make ratios more stable than individual readings. As far as variation within a season is concerned, the use of ratios in classification is often unsatisfactory. The correlations show also that the accuracy of the mean of two sides is little greater than that of the measurement of one side alone. The only advantage, therefore, of measuring a second side is that it provides a quick check on the measurement of the first.

7. Summary.

At least 30 specimens of each form of *Macrosiphum rubiellum*, Theobald, and *Aphis idaei*, van der Goot, were collected, mounted and their principal organs measured.

Correlations were calculated between different parts on the right side and the conclusion reached that the ratios of lengths of organs were unstable characteristics of the species examined. High correlations were obtained between the same part on different sides of the body.

The mean values and standard errors are tabulated and a method given for assigning limits of variation within a species. The standard errors obtained were of the order of 7 per cent. of the mean.

The asymmetry, kurtosis and skewness of the distributions were calculated to test the effect of possible non-normality on the foregoing work.

Acknowledgments.

The writers wish to express their indebtedness to Mr. F. Laing for criticisms of the entomological aspects of the work, to Mr. T. N. Hoblyn for advice on the statistical procedure, and to others who read the manuscript and offered suggestions.

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ON THE WING FORMS OF *ANOPHELES FUNESTUS*, GILES.

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In a previous paper (Leeson 1937) it was shown that in East Africa there were variations in the wing markings of the type form of *Anopheles funestus*. It was further shown that larvae and pupae positively identified as typical *A. funestus* produced adults having these wing markings. Identification of the adults was confirmed by examination of pharyngeal armatures and male terminalia. The wing forms were then arranged in the following four groups :—

Group 1 : dark area at base of costa uninterrupted, 3rd vein with a pale interruption. *Group* 2 : dark area at base of costa uninterrupted, 3rd vein entirely dark. *Group* 3 : dark area at base of costa interrupted by one pale spot, 3rd vein with a pale interruption. *Group* 4 : dark area at base of costa interrupted by one pale spot, 3rd vein entirely dark.

The first group was commonest inland and the third group at the coast. The fourth group was rare.

Recently, through the kindness of Dr. W. A. Lamborn, I have been able to examine the wings of three collections of *A. funestus* from Fort Johnston, Nyasaland. The first consisted of individual females and the adults reared from eggs laid by them, from May to July 1938. The result of the examination is summarised in the following table :—

Parents		Progeny (♂ and ♀ together)				Total progeny
Wing group	No. of females	1	2	3	4	
1	3	14	19	0	3	36
2	11	8	83	0	2	93
3	1	3	10	0	0	13
4	0	0	0	0	0	0
	15	25	112	0	5	142

Though the numbers are small yet certain observations appear to be worthy of record.

Wing Group 1.—Parents in this group produced adults with wings of their own group and adults having wings of groups 2 and 4.

Wing Group 2.—Parents in this group produced adults with wings of their own group and adults having wings of groups 1 and 4.

Wing Group 3.—The only parent in this group produced adults with wings of groups 1 and 2 but none having wings of her own group. None of the adults of the second generation had wings of this type.

Wing Group 4.—None of the parents belonged to this group though some of the bred adults had wings of this type.

The other two collections consisted of caught specimens and were distributed as follows :—

Wing groups	1	2	3	4	Total
Collection 1 (no date)	28	21	1	0	50
Collection 2 (July 1938)	76	221	10	8	315
	104	242	11	8	365

These observations show that a female of the type form of *A. funestus* may produce adults having wings of any form and not necessarily of her own. It may also be remarked that adults having wings of the third group (the suggested coastal form) and of the fourth group (rare in East Africa) make together only 5 per cent. of the three collections ; that adults of the second group (dark wings) amount to about 70 per cent. and that the remaining 25 per cent. belong to group 1. All the specimens were collected in May, June and July 1938, the dry season, but though there seems to be some support for the view that dry-season specimens have dark wings (Leeson 1930), yet in the absence of specimens collected at other seasons for comparison it still remains to be shown whether or not there is any seasonal variation in the wing-markings in this species.

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A NEW AFRICAN DIAPRIID (HYM., PROCTRUPOIDEA).

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Through Dr. O. W. Richards, the Imperial Institute of Entomology has recently received for identification specimens of a *Trichopria* parasitic on two species of tsetse-flies. It appears to be new and, since it may play a part in the control of its hosts, is described below.

Subfamily Diapriinae.

Trichopria lewisi, sp. n. (fig. 1).

♀. Black. Apical 5–6 segments of the antenna blackened; rest of antenna amber-coloured. Legs amber-coloured.

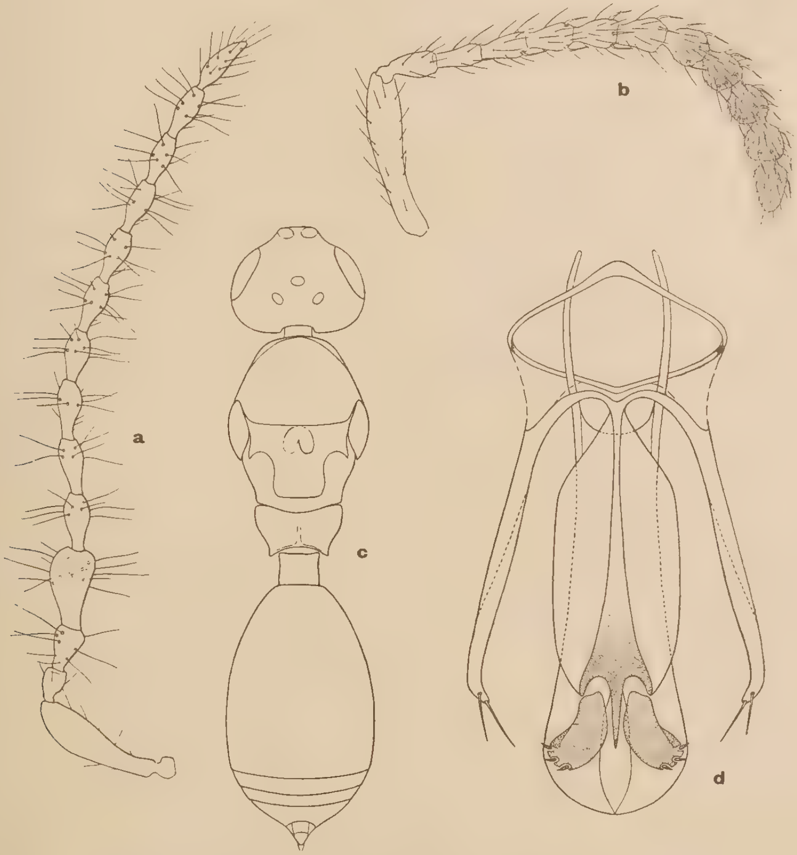

Fig. 1. *Trichopria lewisi*, sp. n.: **a,** antenna, ♂; **b,** antenna, ♀; **c,** body, ♀; **d,** genitalia, ♂.

Head almost spherical, evenly convex above, strongly and evenly rounded at the sides, slightly narrower than the thorax ; seen from above, slightly transverse, 7 : 6 ; seen from in front (the top of the posterior ocelli being just in view), hardly wider than long, 21 : 20. Eyes with about 4–6 long, erect hairs. Ocelli arranged in a triangle whose base is much longer than its sides. Posterior lateral surface of the head with fine, dense, very short, brownish pubescence ; in a lateral view of the head, this pubescence is quite inconspicuous. Antennae (fig. 1, *b*) : scape strongly compressed over a little more than basal half (this is not shown in figure owing to position of scape) ; when viewed so that the compressed part is seen at its narrowest, greatest width of scape about 3 times narrowest ; flagellum rather strongly hairy, not much thickened to apex ; no trace of a differentiated club ; segments 6–9 more or less moniliform. *Thorax* : pronotum, seen from above, visible at shoulders, disappearing from view about half way between the shoulder and tegula ; only a thin collar of brownish pubescence present. Propleura, when the head is removed, shining and almost bare on each side of the mid-line, more especially towards and around the neck. Mesonotum on the whole evenly convex, not at all impressed on each side posteriorly. Scutellum anteriorly with two foveae which in front are confluent without a trace of separation ; shield proper with the merest trace of a keel on posterior half. Propodeum : posterior margin only feebly emarginate ; upper lateral teeth hardly indicated ; dorsal areas polished, with pubescence so very thin as hardly to give them a brownish appearance. Metapleura with thin, brownish pubescence. Legs : front tibia above at apex with a thin, spiniform projection which is a little longer than segment 2 of the front tarsus and fully one-third the length of segment 1. Wings apparently typical for the genus. *Abdomen* : exposed part of petiole short, slightly transverse, having only a very little modified pubescence posteriorly, otherwise markedly bare (for the genus) and shining ; abdomen beyond the petiole rather broadly fusiform, markedly wider than the thorax ; tergites 3–5 with the merest trace of microscopic puncturation, visible at a magnification of ×90.

♂. Like the female except for the usual sexual differences. Antennal scape compressed as in the female, but the compressed part occupying a little less than basal half (owing to position of scape, figure 1, *a*, does not show the degree of modification) ; flagellar segment 2, strongly dilated and, viewed edge on, appearing deeply emarginate, the inner, concave surface being polished and bare ; all the flagellar segments with very long hairs, arranged more or less in whorls, though rather less so on the more apical segments. Genitalia (fig. 1, *d*).

Length : ♂♀, 2 mm.

KENYA COLONY : Kabete, 25 ♀♀, one the type, 1 ♂, bred from puparia of *Glossina brevipalpis*, Newstead, and *G. fuscipleuris*, Austen (*E. A. Lewis*).

Type in the British Museum.

So far as I can make out, this species differs from all other described African species in that the antenna of the female possesses no differentiated club. It is probably largely characterised by the inconspicuousness of the pubescence on those parts where, in the genus, pubescence is usually a striking feature, namely on back of head, pronotum, sides of propodeum and petiole.

I have pleasure in naming this species in honour of its collector, Dr. Lewis.

NOTES ON ETHIOPIAN ANOPHELINI.

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South African Institute for Medical Research, Johannesburg,
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Anopheles walravensi, Edw.

Edwards (Bull. Ent. Res., 1930, **21,** p. 290) originally described this species from the Belgian Congo. Two further adults from Ndola, N. Rhodesia, were examined by Evans (Mosquitoes of the Ethiopian Region, II, Anophelini, 1938, p. 246) who noted that these differed from the type species in having the costa without a pale sector spot and the third vein with a large dark area at the apex. The present specimens (also from Ndola) show that these differences are not constant ; in one of the two females there is a small sector spot present on one wing, the other wing and both wings in the second female have no sector spot, both females have a rather small dark area at the apex of the third vein. In two of the three males a sector spot is present on both wings, while in the third specimen this spot is absent from both wings. On the whole the wings may be said to be darker than those of typical *walravensi* from the Congo, and these Ndola specimens may be taken as representing a darker form but not worth subspecific rank. Associated with these five adults were four larval pelts and five pupal pelts obtained from isolated specimens. We therefore take this opportunity of describing the larva and pupa.

Larva (fig. 1, *b*, *d*, *e*, *g*, *i*, and fig. 2, *b*).

Head : clypeus with a central longitudinal pigmented area which runs from the posterior border of the clypeus to the anterior border of the head : post frontal hair simple or bifid ; vertical hair simple or bifid but in one instance with three branches on one side ; inner clypeal long and simple ; outer clypeal simple, about half the length of the inner ; posterior clypeal delicate, simple, about as long as the outer ; antennae with spines sparsely scattered over the whole of the shaft ; shaft hair small, situated near the base ; apical hair with 4–5 branches. *Thorax* : inner and middle submedian thoracic hairs well separated basally but neither hair much expanded ; both long mesothoracic bristles simple, one long prothoracic and metathoracic bristle feathered as in group I of Evans ; palmate hair with 12–16 narrow undifferentiated leaflets, the longest of which measures about 68μ. *Abdomen* : palmate hairs as follows :—on segment I with about nine narrow leaflets, some simple but others showing development of a filament ; II with 13–15 narrow leaflets and short poorly demarcated filaments ; III–VII with 13 to 17 well developed broad leaflets having broad serrated shoulders and short sharp filaments, the leaflets and filaments together measure about 60μ in length and the longest filament 16μ ; pecten with six long spines and seven short ones ; lateral arms of the median plate of the scoop very poorly developed ; saddle hair with three or four branches ; tergal plates well developed, the width of that on segment V being very nearly equal to half the distance between the palmate hairs ; a single prominent accessory tergal plate present.

Evans suspected that the larva of this species might show affinities with those of *theileri* and *distinctus* ; this, however, is not so. The larva is apparently very closely related to that of *harperi*. The simple saddle hair and closely approximated submedian thoracics of *harperi* should serve to distinguish the two.

PUPA (fig. 1, *l*).

Paddles only slightly longer than the greatest width; external border with a fringe of delicate spines which reach to the apical border but not to the base; apical border as far as the terminal hair with delicate hairs; apical hair hooked; accessory hair delicate with 6–7 branches. *Abdomen*: spine A on VIII long with 5–11 branches; on VII–V less than half the succeeding segment; small on IV; minute on III and II. Bristle B on VII about as long as segment VIII with 5–6 branches; on VI nearly as long as segment VII with 5–8 branches; on V about three-quarters the length of segment VI with 5–7 branches; on IV a little over half the length of segment V with 7–9 branches. Bristle C on VII longer than segment VIII, simple, split at the tip or bifid; on VI as long as or longer than segment VII with 2–4 branches;

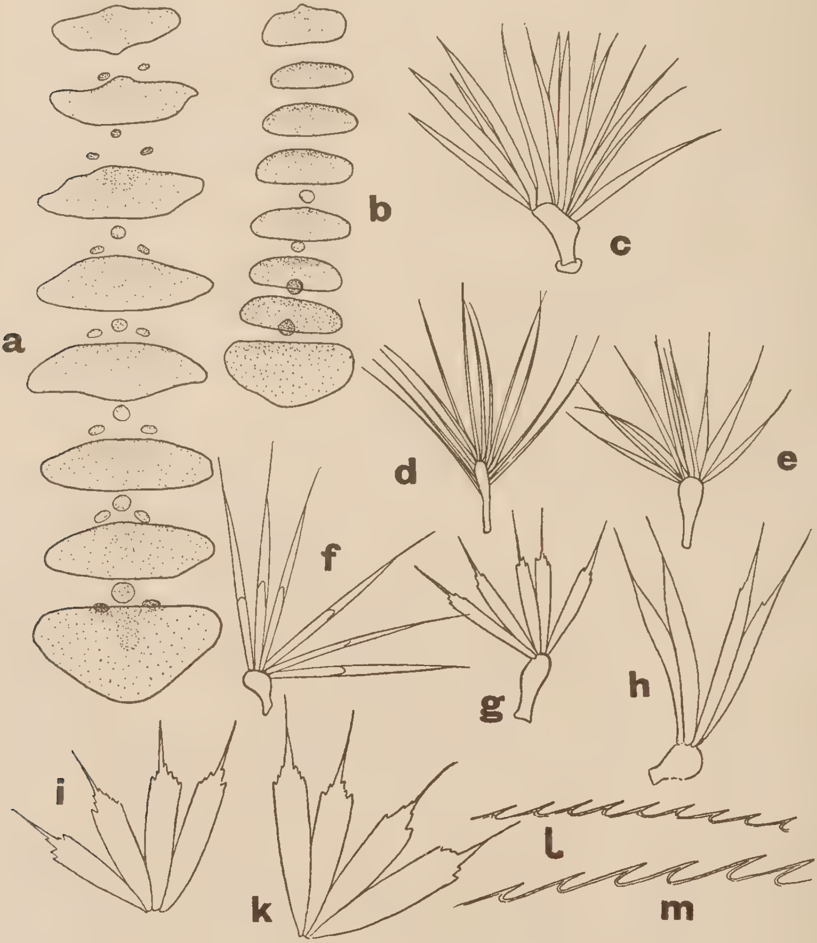

Fig. 1. *Anopheles michaeli*, sp. nov.: **a**, abdominal tergal plates; **c**, thoracic palmate hair; **f**, first abdominal palmate hair; **h**, second abdominal palmate hair; **k**, fourth abdominal palmate hair; **m**, portion of the external border of the paddle of the pupa. *Anopheles walravensi*, Edw.: **b**, abdominal tergal plates; **d**, thoracic palmate hair; **e**, first abdominal palmate hair; **g**, second abdominal palmate hair; **i**, fourth abdominal palmate hair; **l**, portion of the external border of the paddle of the pupa.

on V shorter than segment VI with 7 branches ; on IV shorter than segment V with 7–9 branches. Bristle C^1 simple or with the end split into 3–4 branches. Bristle D on VII simple, longer than segment VIII ; on VI simple, longer than segment VII.

Described from material collected at Ndola, Northern Rhodesia, by Dr. R. B. Jackson.

Anopheles michaeli, sp. nov.

A medium-sized species resembling *walravensi* in general appearance, but with the central portion of the mesonotum clothed with yellowish scales.

♀. *Head* : upright scales mainly white but dark posteriorly ; three pale bands on the palps, the two apical ones together about equal to, or slightly longer than, the intervening dark band. *Thorax* : mesonotum densely clothed with numerous moderately broad scales which appear to be somewhat broader than in *walravensi* ; unlike that species, however, only the scales on the anterior border of the mesonotum and those extending from above the wing roots are white, the rest, that is almost the whole of the central portion of the mesonotum, are distinctly yellowish. *Legs* as in *walravensi*. *Wings* (fig. 2, *a*) : costa almost entirely dark and the dark areas on the

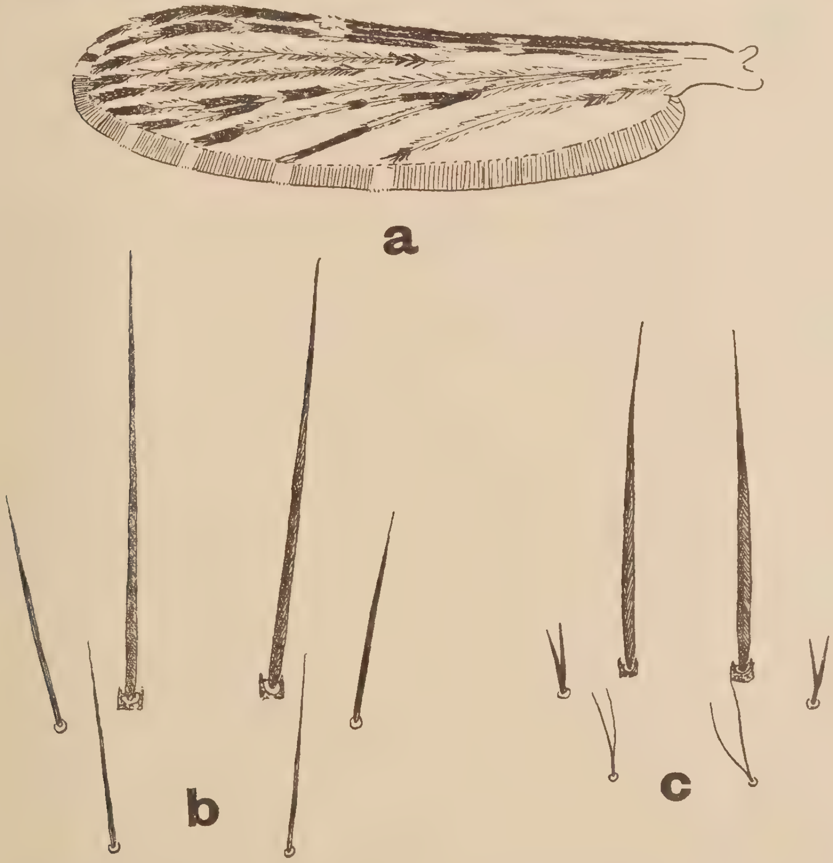

Fig. 2. *Anopheles michaeli,* sp. nov. : **a,** female wing ; **c,** larval clypeal hairs. *Anopheles walravensi,* Edw. : **b,** larval clypeal hairs.

wing field somewhat reduced but not as much as in *walravensi* var. *milesi*; the pale spot on the costa opposite the fork of the second vein is poorly indicated in one specimen but distinct in another.

♂. As in the female but pale spot on the costa opposite the end of the fork of the second vein more distinct. *Terminalia* as described for *walravensi*.

Larva (fig. 1, *a*, *c*, *f*, *h*, *k*, and fig. 2, *c*).

The larva is quite distinct from that of *walravensi* as described above and presents a combination of characters different from that of any Ethiopian larva so far described.

Head: pigmentation as in *walravensi*; post frontal hair with from 2–6 branches averaging 4 branches; vertical hair similar, these hairs are therefore on the average more branched than in *walravensi*; inner clypeals long and simple, outer very short and split into two, posterior clypeal more delicate, short and split into two; antenna as in *walravensi*. *Thorax*: inner and middle submedian thoracics with their basal tubercles closely approximated; pleural hairs as in *walravensi*; palmate hair with about 18–20 narrow undifferentiated leaflets. *Abdomen*: palmate hairs as follows:—on segment I with 13–15 narrow undifferentiated leaflets; II with about 14 narrow leaflets with blade and filament poorly differentiated; III–VII well developed with sloping shoulders and short sharp filaments much as in *walravensi*; pecten with seven long teeth and five short ones; lateral arms of the scoop poorly developed; saddle hair with 3–4 branches; tergal plates very well developed, on segment V at least three-quarters of the distance between the palmates; three accessory plates present on most segments.

Pupa (fig. 1, *m*).

Paddles as in *walravensi* but spines along the exterior border much more pronounced. *Abdomen*: spine A as in *walravensi* but on segments VII and VI about half as long as the succeeding segment. Bristle B on VII with 6 branches about three-quarters as long as segment VIII; on VI with 6–7 branches; on V with 8–9 branches. Bristle C on VII longer than segment VIII, simple, but in one instance split into two; on VI about as long as segment VII and simple; on V with 4–5 branches. Bristle D as in *walravensi*.

Generally the pupa is as that of *walravensi*, but the bristles show much less branching.

The adult of this species is related to *distinctus*, *walravensi*, *walravensi* var. *milesi* and *schwetzi*. The three-banded palp serves to separate it from *schwetzi* and *distinctus* and the yellowish mesonotal scales from *walravensi* and its variety *milesi*. In *distinctus* var. *ugandae* the palp is three-banded, but the broad mesonotal scaling in *michaeli*, sp. nov., should serve to separate the two. The larva and pupa are quite distinct from those of *distinctus* and its variety *ugandae* and *walravensi*, these stages have not been described in *schwetzi* and *walravensi* var. *milesi*.

The species is named in honour of Mr. Michael Viljoen, of Ndola, who drew our attention to certain larval differences among supposedly *walravensi* material.

Described from 3 males and 3 females and their associated larval and pupal pelts obtained from specimens reared in isolation. Ndola, Northern Rhodesia (Michael Viljoen).

Anopheles tchekedii, sp. nov. (fig. 3).

This Anopheline was taken in 1935 at Okavango Swamp, Bechuanaland, by Dr. W. A. Lamborn. He says it was "very numerous, biting in the late afternoon, cattle being literally covered with them." Some badly damaged specimens received at the British Museum from Dr. Lamborn in 1935, and recorded by Evans (1938) as "probably *distinctus*," belong to the same batch as those described below.

♀. *Head*: upright forked scales white, except posteriorly where they are black at the sides and yellow in the middle; in front, some white elliptical scales; frontal tuft white. *Antennae*: a few white scales near base. *Palpi*: three narrow pale bands; third pale band on last segment does not extend to apex so that tip of palp is dark. *Thorax*: integument of mesonotum grey with a narrow median longitudinal dark line expanding posteriorly into a wider dark bare prescutellar area. Fossae dark brown and without scales. Anterior half of mesonotum and middle portion of posterior half clothed with whitish, broadly elliptical scales. A narrow line of scales along the border of the grey mesonotum extends backwards to the wing roots in front of which it widens into a patch; the scales nearest to the wing roots are narrow curved. Some pale scales on scutellum. *Legs* dark brown, paler below. Forelegs with narrow pale rings at apices of first, second and third tarsal segments. Mid and hind legs without these pale rings. *Wings*: pale scales creamy. Costa mainly dark with a subapical and apical pale spot. Subcosta all dark. First longitudinal vein pale at base and a pale subapical spot, remainder either all dark or with one other small pale interruption. Upper branch of second longitudinal vein either all dark or with some pale scales in the middle; lower branch pale in the middle third. Third long vein with two short dark spots near base and a longer one distally. Fourth long vein with stem mainly pale but with a dark spot before bifurcation; upper and lower branches with a dark spot near each end. Fifth long vein, upper branch dark distally and a small dark spot on each side of the cross vein; lower branch dark distally; dark spot across bifurcation; stem mainly pale. Sixth long vein with two or three dark spots. Fringe with pale spots at ends of veins except sixth and lower branch of fifth; some pale border scales in basal portion of wing. *Abdomen*: cerci without scales.

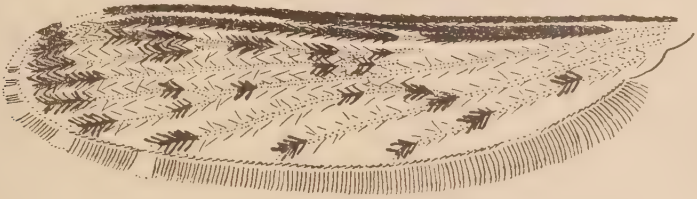

Fig. 3. Wing of *Anopheles tchekedii*, sp. nov.

This species differs from *walravensi* and from *michaeli* in having no pale spot in the middle of the costa; from *walravensi* in having the tip of the third long vein more broadly dark, and in having no pale fringe spots at the ends of veins 5·2 and 6. From *michaeli* this species may also be distinguished by the dark tips to the palps. The mesonotal scales are broader than in typical *walravensi* (index about 2) somewhat as in the var. *milesi*, but the latter has a much paler wing.

Cotypes. In British Museum and London School of Hygiene and Tropical Medicine.

Anopheles argenteolobatus, Gough.

Among several typical adults bred from larvae one female had the hind tarsi minutely tipped with white.

Luanshya, N. Rhodesia (C. Payne).

Egg (fig. 4). A long slender egg averaging 0·54 mm. in length and 0·12 in width. Very similar to that of *pharoensis*, Theo. The dorsal surface is very extensive, convex, and the whole shell is finely and evenly stippled. The frills are narrower than in *pharoensis* and the floats much shorter, each containing only 12–15 ridges. Described from two batches obtained from different females by Dr. R. B. Jackson, Ndola, N. Rhodesia.

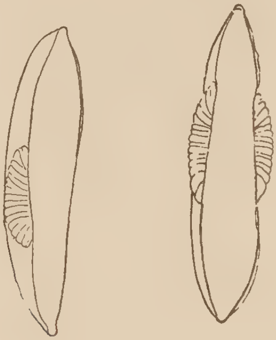

Fig. 4. *Anopheles argenteolobatus*, Gough : egg, dorsal and half side view.

Anopheles domicolus, Edw.

With the second vein dark, as described for the Uganda specimen by Evans. Mesonotal scales may be broader than described for the type, in which they are said to be extremely narrow.

Salisbury, S. Rhodesia (W. Alves). Mufilira, N. Rhodesia (J. S. McLean).

Anopheles distinctus, N. & C.

Egg (fig. 5). Average length 0·46 mm. and width 0·12 mm. Quite unlike that of *theileri* except in the reticulation of the lower surface, which is very feebly indicated and only seen in the very best light. Upper surface finely stippled and unbroken. Frill very poorly developed and seen only as a faint white line. Floats small, consisting of about 14 ridges each.

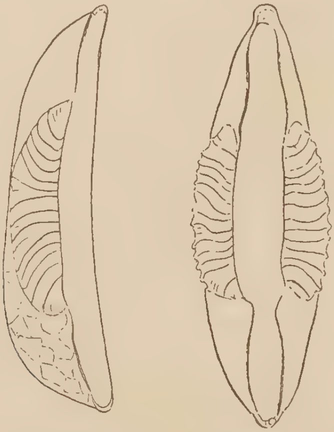

Fig. 5. *Anopheles distinctus*, N. & C. : egg, side and dorsal view.

Described from several batches obtained by Dr. R. B. Jackson at Ndola, N. Rhodesia.

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THE EFFECT UPON *GLOSSINA* OF CHANGING THE CLIMATE IN THE TRUE HABITAT BY PARTIAL CLEARING OF VEGETATION.

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(Plates I & II.)

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General Introduction.

The experiment took place at Gadau (12°N., 10°E.) in Northern Nigeria, where climatic conditions are very severe and where both *Glossina morsitans* and *G. tachinoides* concentrate within dense residual forest islands for protection from the high temperature and evaporation of the late dry season ; these forest islands form the true habitat for tsetse and occur in the plain of the Katagum River, which constitutes the fly-belt (Nash 1937).

Despite the denseness of the vegetation forming a forest island, earlier experiments indicated that for a short period in the late dry season both species of tsetse live very close to their upper critical temperature zone (102°–106°F.), even though they take advantage of the coolest sites on the ground during the heat of the day (Nash 1936 *b*). It was concluded that if the peripheral and intrusive thicket windbreaks of *Dichrostachys platycarpa* were removed, the insulation of the forest islands would be destroyed, hot winds from the open country would sweep through, and possibly the environment would be sufficiently altered to destroy the tsetse without resorting to the destruction of the true forest. The purpose of this paper is to describe the results of an experiment carried out on these lines.

Description of the Experiment.

A forest island which had already been under observation for a number of years was selected for the experiment. This island was linked to another by a series of small thickets which were ruthlessly cleared in April 1936, making a barrier of

330 yards between the Experimental and Control Forest Islands (Plate I, fig. 1). It was realised at the time that so small a barrier would only be effective in the hot weather, and that any success attained at this season in exterminating the tsetse population of the Experimental Island would be vitiated by re-infestation from the Control and elsewhere during the ensuing rains. This would not matter, as naturally, if the method proved successful, it would not be applied on the large scale without constructing adequate barriers. Marking experiments showed that both species crossed the clearing freely during the rains, but that in very hot weather no *G. tachinoides* and only one per cent. of the *G. morsitans* marked in the Experimental Forest Island succeeded in reaching the Control.

The Experimental Forest Island is 575 yards long with an average width of 87 yards, giving an area of about 10·3 acres; the Control is 640 yards long with an average width of 50 yards and an area of about 6·6 acres.

The investigation was divided into three periods :—

1. *The Control Period* (April 1936–Sept. 1937).—The climates of the two islands were studied for eighteen months, and were found to be very similar. Readings were taken in each forest island from a recording thermo-hygrograph and Livingston white atmometer at four feet, and from a maximum thermometer at 1½ inches depth.

An index of the relative fly densities of the two islands was obtained from fly-rounds, and of pupal densities from puparia-rounds; data were acquired on pupal mortality by burying puparia in a copper-netting box at 1½ inches depth (*vide* Nash 1939).

2. *After Removal of Thicket Windbreak* (Oct. 1937–Sept. 1938).—In October 1937 the impenetrable, bramble-like thicket surrounding the Experimental Forest Island was cut down and dragged away (Plate I, fig. 2), and the trunks of the huge creepers which festooned the tops of the forest trees were severed but left *in situ*. No timber was destroyed, not a single tree being cut down in the true forest; even dense stands of seedling ebonies (*Diospyros mespiliformis*) were left untouched (Plate II, fig. 1). The cost worked out at £1 2s. 8d. or 68 man-days per acre. Fire was excluded, as it was feared that the rich humus might become ignited and that the dried and hanging creepers would burn and destroy the forest, thus ruining the experiment.

The effect of these measures upon the climate and the fly was then studied for a year. Evaporation at 5 inches, and the soil water-content on the 15th day of each month at 1½ inches depth, were recorded from the beginning of this period.

3. *After Thinning the Seedling Ebonies* (Oct. 1938–Sept. 1939).—As it had been found that *G. tachinoides* still persisted in small numbers in the Experimental Forest Island, the seedling ebonies were thinned in October 1938 until they no longer formed clumps (Plate II, fig. 2). The cost was 5s. 8d. an acre or 17 man-days, which together with the initial cost works out at £1 8s. 4d. or 85 man-days per acre; this is a little less than half the cost of totally clearing very heavy forest of this type. If, instead of dragging the cut thicket to a safe distance outside the forest, it had been burnt *in situ* as would normally be done, considerable savings could have been made. The combined effects of these measures were observed for a further year, and fire was again excluded. The forest floor was first invaded by grass in June 1939.

Effect of Partial Clearing on the Climate.

By plotting the mean monthly evaporation and maximum shade temperature at four feet on the two ordinates and by joining the points by a line in the order of months, a series of climatographs have been constructed for the Control and Experimental Forest Islands (fig. 1). The climate in each is shown for a year of the initial control period, for a year after the removal of the thicket windbreaks from around the Experimental Island, and for a year after the thinning of the seedling ebonies. The dotted lines, showing the intersection of 100°F. and 50 cc., are intended as a guide to the eye. (N.B. The mean *maximum* temperature has been used in preference to the mean temperature because the partial clearing has made the Experimental Forest Island colder at night, thus reducing the mean temperature and masking the important diurnal increase.)

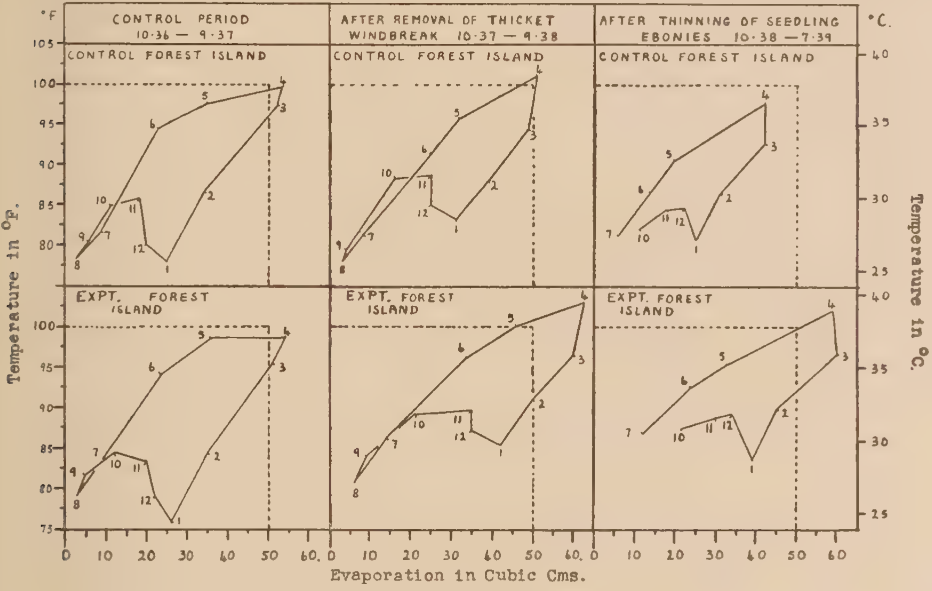

Fig. 1. Climatographs for the two Forest Islands based on mean monthly maximum shade temperature and evaporation.

In the Control period the climate in the two forest islands was extremely similar. Note the typical annual cycle :—The low temperature and evaporation of the heavy rains (months 8–9), the rising temperature and evaporation of the early dry season (10–11), the drop in temperature and yet higher evaporation of the cold mid-dry season (12–1), the tremendous rise in temperature and evaporation of the hot late dry season (2–4) and, lastly, the gradual return to less severe conditions throughout the early rains (5–7).

In the year following the removal of the Experimental Forest Island's thicket windbreak the cold season was less pronounced, but the climate of the Control was otherwise much the same as in the first year. In the Experimental Island, however, great changes had taken place ; throughout the dry season and early rains (11–6) the evaporation was greatly increased and the temperature a little higher than in the Control. In the extreme months (3–5) the mean evaporation exceeded that of the Control by 11–14 cc. a day, but the mean maximum temperature by only 2·1°–4·4°F. (1·2°–2·4°C.). Note how four months lie in, or outside, the dotted " 100°F. and 50 cc." line on the curve for the Experimental Forest Island, as against only one for the Control.

The late dry season of the third year, which followed the removal of the seedling ebonies, was abnormally mild, as witness the picture for the Control. Even so, in March and April the evaporation in the Experimental Forest Island was from 17–18 cc. per day greater than in the Control, whereas the mean maximum temperature was only 4·0°–4·4°F. higher.

Partial clearing has plainly intensified the climatic conditions within the Experimental Forest Island—particularly evaporation, which has become some 40 per cent. greater than in the Control during the late dry season.

The meterological data collected are too extensive for publication, but in Table I the data are given for the very hot month of April for the three years of the experiment.

Originally the climates of the two islands were almost identical, as can be seen under April 1937.

The partial clearing of the Experimental Forest Island produced relatively slight alterations in the shade temperature at four feet above the ground surface. This island used to be a little cooler than the Control in the day and slightly warmer at night, but after clearing it became somewhat hotter in the day and a little cooler at night ; its mean temperature range was finally increased by about 5°F. (2·8°C.) over that of the Control. Admittedly, absolute maxima occurred that were several degrees above the upper fatal limit for both species, but, as will be shown later, this is immaterial, as the tsetse can avoid these dangerously high temperatures by retreating into much cooler microclimates. Judging from the maxima at 1½ inches depth, the soil temperature has been considerably increased, a change which might be expected to lead to an increase in pupal mortality.

TABLE I.

To show the Effect of Partial Clearing upon the Climate of a Residual Forest Island in one of the hottest and driest Months.

Climatic factor	April 1937			April 1938			April 1939		
	Before partial clearing			After removal of thicket windbreak			After thinning of seedling ebonies		
	E	C	E−C	E	C	E−C	E	C	E−C
Mean evap. cc. 4 ft.	54	53	*+1*	63	51	*+12*	59	42	*+17*
*Mean sat. def. mm. 4 ft. ...	19·1	18·0	*+1·1*	23·2	18·7	*+4·5*	19·2	15·4	*+3·8*
*Mean t. °F. 4 ft.	83·5	83·0	*+0·5*	89·0	87·5	*+1·5*	88·5	85·5	*+3·0*
Mean max. t. °F. 4 ft.... ...	98·7	99·5	−0·8	103·1	101·0	*+2·1*	102·0	97·6	*+4·4*
Absolute max. t. °F. 4 ft. ...	105·0	105·5	*−0·5*	110·0	106·0	*+4·0*	107·0	102·5	*+4·5*
Mean min. t. °F. 4 ft.	69·2	68·6	*+0·6*	75·7	76·4	*−0·7*	74·1	74·6	*−0·5*
Absolute min. t. °F. 4 ft. ...	57·0	55·0	*+2·0*	64·5	65·0	*−0·5*	62·0	65·5	*−3·5*
Mean max. sat. def. mm. 4 ft.	35·8	35·3	*+0·5*	41·7	35·1	*+6·6*	34·8	29·0	*+5·8*
Mean evap. cc. at 5 in. ...	—	—	—	57	54	*+3*	50	42	*+8*
Mean max. t. °F. at 1½ in. depth	88·2	87·1	*+1·1*	97·2	91·8	*+5·4*	99·9	91·9	*+8·0*
Absolute max. t. °F. at 1½ in.	90·5	91·4	*−0·9*	99·5	94·1	*+5·4*	103·1	94·1	*+9·0*
Soil water content (per cent.) at 1½ in.	—	—	—	4·0	6·4	*−2·4*	4·6	5·6	*−1·0*

Note.—E, denotes Experimental Forest Island.
C, denotes Control Forest Island.
E−C, denotes the amount by which the Experimental Island differs from the Control.
*, denotes true means obtained with a planimeter from the thermo-hygrograph charts.

The evaporation at 4 feet shows a tremendous increase over that of the Control, suggesting that it may prove a very important factor. At 5 inches above the surface, the difference in evaporation rates was small until after the thinning of the seedling ebonies.

The mean saturation deficiency has risen appreciably. But the mean maximum saturation deficiency, obtained from the thermo-hygrograph charts at the time when the temperature was highest, shows a considerable increase and has reached a figure which is well above the zone of 18 to 26 mm., which was suggested as optimum for *G. tachinoides* by Buxton & Lewis (1934). (N.B. Actually those authors give the zone as 6 to 14 mm., but it is obvious that they have made a mistake in the conversion of their temperature and humidity data, and that the zone should be 18–26 mm.) Since the saturation deficiency remains well above this zone for a considerable period each day at this season, it may be an important factor.

The soil water-content, expressed as a percentage of dry weight, is a little lower in the Experimental Island. The difference appears small, but is probably enough to prevent the soil atmosphere in this island from remaining saturated, which is important for puparia, as will be mentioned later.

Effect of Partial Clearing on the Fly.

All the fly data for the Control and Experimental Forest Islands are shown on figs. 1 and 2. The data for adult and pupal density have been plotted on a logarithmic scale which indicates *rate* of increase or decrease. It follows that if two curves on the graph run parallel with each other, they must denote identical rates of increase or decrease. On the scale employed a 25 per cent. decrease in density will correspond to a curve falling at an angle of 20°, 50 per cent. at 35°, 100 per cent. at 50°, 200 per cent. at 61°, and 500 per cent. at 71·5°. Another reason for using a logarithmic scale is that it gives the low readings full expression at the expense of the high ; clearly it is the low readings which are of great importance in an experiment aimed at the destruction of an insect population. The length of the fly-round used for the Experimental Forest Island was 1,837 yards, and for the Control 1,356 yards ; to standardise the results the adult densities are expressed as flies per boy 1,000 yards (F.B. 1,000 Y.). Similarly, on occasion the number of puparia searchers varied, so that pupal density is expressed as puparia per boy day of 4 hours (P.B.D.). Very low densities varying from 1·0 to 0·1 cannot be plotted on the scale employed, because the logarithm of 1 is 0 ; hence if the density was not actually 0, the real figure has been inserted above.

Fly-rounds were carried out simultaneously in the two forest islands from four to six times a month ; the mean monthly figure has been used as the index of adult density. Puparial rounds were carried out in the Experimental Island on the 1st and 2nd days of each month, and in the Control, on the 3rd and 4th days.

The results for each species will be described separately :—

Glossina tachinoides (fig. 2).

1. *The Control Period* (March 1936–Sept. 1937).—For nineteen months the seasonal fluctuations in adult density were usually similar in the two islands. If the monthly densities from each are plotted against each other the resultant points tend to fall along a straight line, showing that the Control was reasonably satisfactory.

Breeding in residual forest islands is confined to the dry season and early rains, tsetse breeding in the open woodland in the heavy rains (Nash 1939). The puparial rounds were started in September 1936, and for the nine months of the breeding season fluctuations in pupal density were fairly similar. Note that puparia were more numerous in the Control Island.

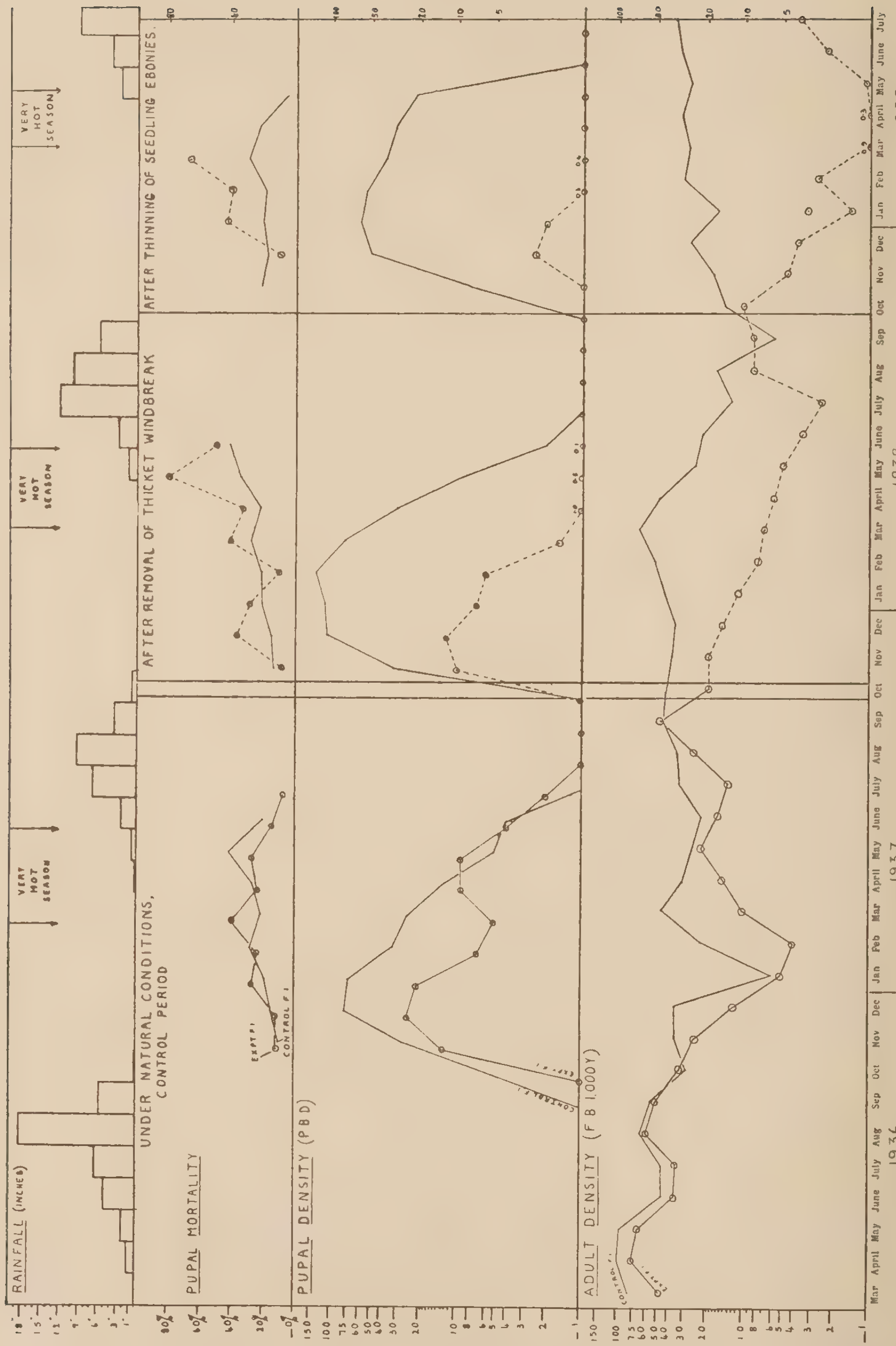

Fig. 2. The effect upon *G. tachinoides* of the partial clearing of a residual forest island. (Pupal density expressed as puparia per boy day of four hours and adult density as flies per boy 1,000 yards; both plotted on a logarithmic scale.)

The pupal mortality percentages were often erratic owing to small numbers, but there is no evidence that the puparia of one forest island were persistently healthier than those of the other.

No startling differences were observed from data on adult sex ratio and hunger.

2. *After Removal of Thicket Windbreak* (Nov. 1937–Sept. 1938).—The removal of the thicket in October 1937 resulted in a fall in the adult density in the Experimental Forest Island, but this fall was not continued until after the evaporation (*not* temperature) rose sharply in November. A steady decrease in population took place at an average rate of 30 per cent., culminating in a density of only 2·4 F.B. 1,000 Y., in July 1938. As expected, the Experimental Forest Island became re-infested during the heavy rains owing to the lack of adequate barriers. In the meanwhile the density in the Control rose to a peak in March and subsequently started to fall, first as a result of the severe climatic conditions of the late dry season, and then as the usual exodus to the open woodland started in the early rains.

Pupal density in the Experimental Island was not immediately affected by the clearing, but rose and became maximal in early December ; it then started to fall, in conjunction with decreasing adult density, until by early April breeding had almost ceased, this being some three months earlier than usual. Meanwhile, in the Control pupal density became maximal in early February, resulting in peak adult density in the following month ; breeding did not cease until the rains, when it shifted to the adjacent open woodland.

The puparia of the Experimental Forest Island were far less healthy than those of the Control throughout the breeding season.

The effect of partial clearing on nutrition was that the percentage of gorged males became consistently greater in the Experimental Forest Island. The sex ratio remained normal until the advent of the hot dry season, when the female percentage suddenly rose, reaching 67 per cent. in May ; it then fell gradually, becoming normal at the end of the rains.

It may be concluded that removing *only* the thicket windbreak from a forest island has a strong adverse effect upon the *G. tachinoides* community, greatly reducing the population and increasing the pupal mortality.

3. *After Thinning the Seedling Ebonies* (Nov. 1938–July 1939).—Owing to the infiltration of tsetse during the cool, humid months of the rains the fly density in the Experimental Forest Island had risen to normal by the end of the wet season. In October 1938 the seedling ebonies were thinned by hoeing up the smallest and only leaving those that were clean-boled and four feet or more in height (Plate II, fig. 2).

In the early dry season evaporation started to rise and adult density to fall. The sharp drop in January, which also occurred in the Control, should be ignored, as it relates to inactivity induced by the cold spell and not to decrease in population (Nash 1937). If this figure is ignored, the average rate of decrease in the population from November to February inclusive was 22 per cent.—a little less than in the last year, when, however, the evaporation for this period was higher (fig. 1). With the advent of the hot weather in March the adult density dropped in one month, at the rate of 174 per cent., to only 0·5 F.B. 1,000 Y ; but the primary cause of this slump was probably the great fall in pupal density and the high pupal mortality which occurred earlier, in the cold, dry weather of January and early February. Since adult longevity is maximal in the cold season (Nash 1936 *a*), fly density would not be drastically affected by the lack of a new generation until the sudden death of the old flies at the onset of the hot weather. Adult density fell to 0·3 F.B. 1,000 Y. in April and did not recover until the rains, when re-population from across the barrier became possible. Meanwhile adult density in the Control remained high throughout the whole period, there being no late dry season fall in this abnormally mild year ;

pupal density followed the usual cycle. Note how pupal mortality was again much higher in the Experimental than in the Control Forest Island.

Despite the abnormally short duration of extreme climatic conditions owing to early rains (fig. 1), and the mats of dead creeper which still thickened the shade canopy owing to the exclusion of fire, adult density was reduced to a figure that is equivalent to one man catching one fly in two miles. It would appear safe to conclude that partial clearing will exterminate *G. tachinoides* in these latitudes.

In the late dry season of 1939, when virtual extermination had been achieved, the rare fly caught was almost always a female ; one would expect the survivors to be females owing to their greater longevity.

The percentage of gorged males continued to be consistently greater than in the Control, which may have been due to improved visibility, but in the late dry season of each year there was a tremendous increase in the percentage. It is suggested that thirst may have been very great in these months owing to excessive evaporation, and that the frequent necessity to replenish abnormal water loss may have caused the flies to seek food when their abdomens were still black with partly digested food from the last meal. The only occasion when the percentage of gorged flies became less than in the Control was in the cold dry month of January 1939, when it fell to zero. It is suggested that since low temperature causes marked inactivity and high evaporation causes rapid water loss, semi-starvation and infrequent feeding may have reduced the breeding rate and thus have caused the great reduction in pupal density in early February which led to the virtual extermination of *G. tachinoides* in the following month. (Jack 1939, has shown that female *morsitans* kept at 24°C. and 50 per cent. R.H. failed to breed regularly if fed less often than every three days.) The mean evaporation for January 1939 was 14 cc. per day greater than in the Control, and the minimum temperatures were slightly lower.

Glossina morsitans (fig. 3).

1. *The Control Period* (March 1936–Sept. 1937).—Reference to fig. 3 shows that the seasonal fluctuations in adult and pupal density were very similar in the two islands. Owing to the small number of puparia found, the pupal mortality data were inadequate.

2. *After Removal of Thicket Windbreak* (Nov. 1937–Sept. 1938).—The removal of the thicket windbreak failed to reduce adult density. A few minor reactions may be noted : In the Control, breeding became maximal in early April leading to a peak density in May, whereas in the Experimental Island breeding became maximal in early March but failed to raise the adult density in the following month, suggesting that conditions became rather too severe in the late dry season ; this is borne out by the higher pupal mortalities and lower pupal densities found in the Experimental Forest Island at this time. In the wet season the removal of the thicket would appear to be of benefit to *G. morsitans* ; instead of adult density decreasing as the flies moved out into the open woodland (*vide* Control from May to September 1938), density remained steady ; possibly better visibility and less humid conditions were the reasons for this failure to emigrate.

3. *After Thinning of Seedling Ebonies* (Nov. 1938–July 1939).—This measure failed to reduced adult density. Throughout the dry season until the onset of the hot weather in March density was consistently greater in the Experimental Forest Island. In the hot months both adult and pupal density were greater in the Control. Partial clearing had no obvious effect upon the percentages of females and of gorged males. Possibly at the same evaporation rate *G. morsitans* loses water much less readily than *G. tachinoides*, and for this reason is much less susceptible to high evaporation.

Conclusions.

1. The partial clearing of a residual forest island leads to the virtual extermination of *G. tachinoides*. It is important to remove all thicket and clumps of seedling trees.

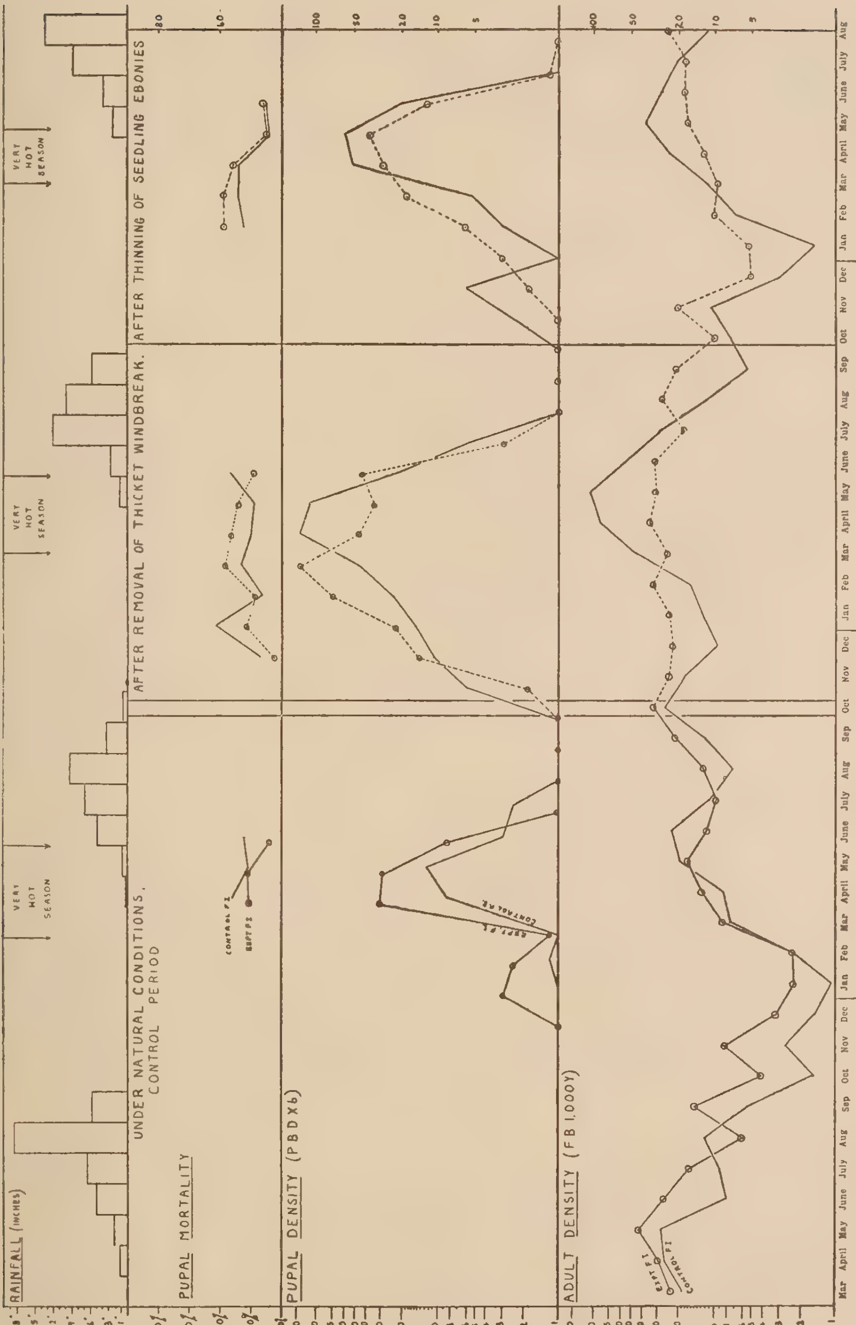

Fig. 3. The effect upon *G. morsitans* of the partial clearing of a residual forest island. (Pupal density expressed as puparia per boy day of four hours and adult density as flies per boy 1,000 yards; both plotted on a logarithmic scale.)

2. Partial clearing is ineffective as a measure against *G. morsitans*. It causes a deterioration of conditions for the fly in the late dry season, but a slight improvement at all other seasons.

3. The very different effects produced by partial clearing on the two species may be due to *G. morsitans* having a greater resistance to high evaporation than *G. tachinoides*; possibly at the same rate of evaporation *G. tachinoides* loses water more readily than *G. morsitans*.

Probable Causes of the Adverse Effects produced.

Before going into this subject it is essential that the normal relationship between evaporation and the dry season concentration of tsetse within forest islands be clearly understood. Both species of tsetse, but especially *G. morsitans*, tend to evacuate the residual forest islands as evaporation falls throughout the rains; as evaporation rises throughout the dry season both species become scarcer in the woodland savannah, the survivors concentrating in the forest islands. Concentration by *G. tachinoides* is complete in early March, but *G. morsitans* being a hardier species waits until April (Nash 1937). It is important to realise that an increasing dry season density in a forest island does not mean that the population is becoming more numerous because the climate is becoming more favourable, but that immigration is overcoming the increasing death rate. It is only when concentration is complete that the harmful effects of high evaporation and temperature become apparent. In this experiment no clearings were made around the two adjacent islands to isolate them from the surrounding woodland, as the prevention of the normal wet season dispersal to drier breeding-grounds might have affected the communities adversely, thus complicating the results. The only clearing made was the 330 yard barrier between the two islands, which, by destroying a chain of small thickets, prevented the passage of flies from the Control to the Experimental Island during the critical late dry season period.

Relative Importance of Evaporation and Maximum Shade Temperature.

Glossina tachinoides.

An attempt has been made to show which factor in the altered climate of the Experimental Island was probably responsible for the virtual extermination of *G. tachinoides* (fig. 4). On the left, the mean monthly fly density and evaporation have been plotted against each other and the resultant points shown with crosses for the Control and with circles for the Experimental Island. On the right, maximum shade temperature and evaporation have been plotted in the same manner. Data are given for the last two dry seasons of the experiment, Period II referring to the seven months following the removal of the thicket windbreak and Period III to the seven months following the thinning of the seedling ebonies. To simplify reference in the text, the points have been numbered with the figure appropriate to the month to which they relate.

Fly Density and Evaporation.

Period II.—The points for the Experimental Forest Island (circles) tend to fall in a straight line, and show that falling fly density was related to rising evaporation. At first sight there appears to be little relationship between fly density and evaporation in the Control (crosses), but the correct interpretation is probably as follows:—From months 10 to 12 density fell as evaporation rose, then immigration started and the continual swarm of new arrivals from months 12 to 3 counteracted the slowly increasing death rate and caused the local density to rise. By March, concentration was complete, and in the absence of new arrivals density crashed in the following month.

Period III.—The scale for fly density has had to be doubled as in the third year the density in the partly cleared island was very low. The steady reduction of fly density in the Experimental Island was again related to rising evaporation. In the Control, concentration started earlier this year and density steadily rose as immigration proceeded. There was no fall in April, probably because the death rate never overcame immigration in this abnormally mild year (fig. 1).

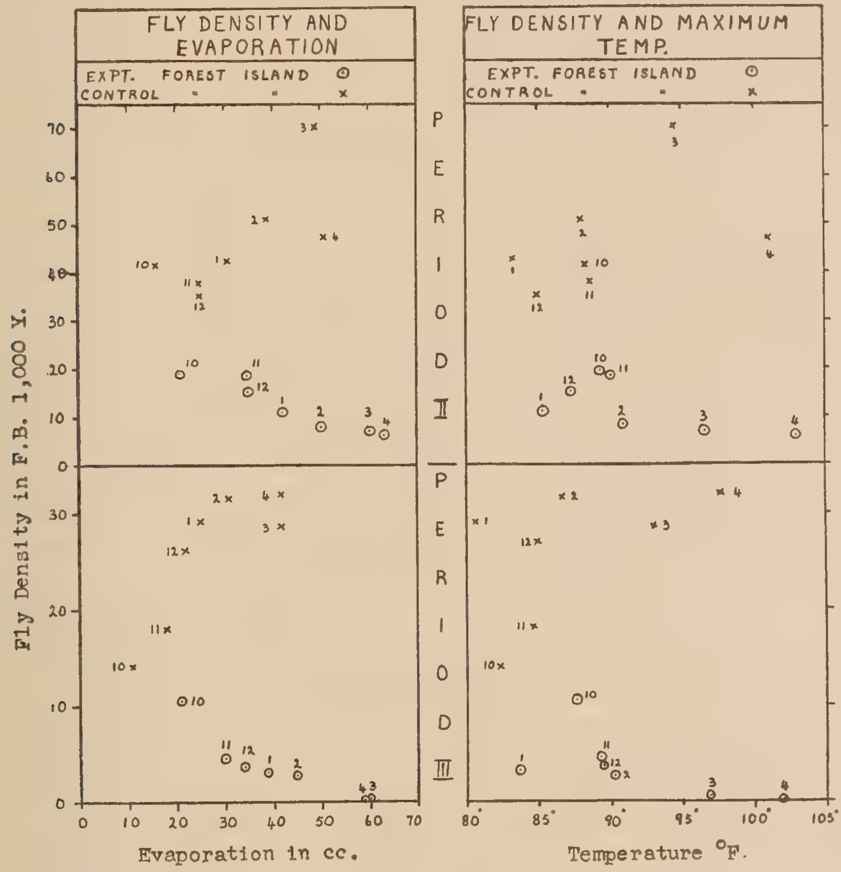

Fig. 4. The relationship between the mean monthly fly density of each forest island and its evaporation and shade temperature at 4 feet.

Fly Density and Maximum Shade Temperature.

Clearly there is no consistent relationship between fly density and temperature. A connexion only exists in the last three months when the temperature is high.

The results shown in fig. 4 suggest that the increased evaporation rate, produced by partly clearing the Experimental Forest Island, prohibited the normal use of this island as a dry season concentration site, and, further, led to the eventual destruction of the existing population. Temperature only appears to be related to fly density in the late dry season. The slump in pupal density and the rise in pupal mortality which led to the extermination of *G. tachinoides* in the Experimental Island occurred in early February, before high temperatures were recorded (fig. 2 and p. 75); this additional evidence confirms the impression that evaporation, not high temperature, was the factor of major importance in the destruction of the *G. tachinoides* community.

G. morsitans.

A graph similar to fig. 4 was made for this species but need not be published. It shows that fly density in the Control increases greatly with rising evaporation, becoming maximal at the very end of the dry season, whereas in the Experimental Forest Island density remains steady or rises very slightly as the evaporation increases. It is believed that the failure of partial clearing to *reduce* the fly density is due to the much greater resistance of this species to high evaporation, which enables it to continue using the partly cleared island as a concentration site ; the increased severity of the environment increases the death rate, but the effects are cancelled by the influx of immigrants which enables the population to remain steady. In the Control, where the death rate is lower, immigration increases the population considerably.

Possible Causes of increased Pupal Mortality.

Buxton & Lewis (1934) found that humidity had great effect upon pupal mortality and concluded that the optimum humidity was at or near saturation, at least for *G. tachinoides*. Their physiological studies showed that unless the air is saturated the puparium loses water, and that it cannot compensate for high evaporation by burning fat or other reserves in order to produce water of metabolism. In 1936 Buxton published a curve showing that the atmosphere in a sample of forest soil from Gadau, which had physical properties almost identical with those of the Experimental Island, would not be saturated if the water content fell below 4·8 per cent. By interpolating the monthly soil water contents recorded for this island on Buxton's curve, it is found that between December and April 1938 and 1939 the soil atmosphere was frequently unsaturated, the humidity ranging from 90–100 per cent. The higher soil water contents recorded in the Control suggest that its soil atmosphere was always saturated. This then is a possible reason for the higher pupal mortalities observed in the Experimental Forest Island. The soil water contents were determined from samples taken at 1½ inches depth, but many puparia are found nearer the surface where the humidity of the soil atmosphere may be considerably lower. It has been shown that decreasing adult density in the Experimental Island is related to increasing evaporation ; a high evaporation rate may have lowered the soil water content near the surface and thus have increased the pupal mortality.

The records of maximum soil temperature at 1½ inches depth show that the partial clearing increased the soil temperature considerably. Since Buxton & Lewis (1934) found that the puparia of both species were healthier at 75°F. than at 86°F., it is probable that increased temperature raised the pupal mortality, especially in the hot late dry season.

Microclimates in relation to Survival.

In an earlier paper the writer described the results of a study of the microclimatic temperature conditions in the late dry season in the Experimental Forest Island ; this was three years before any clearing was undertaken. The lowest temperatures occurred at ground-level, but even in the coolest site under a log a temperature of 98·6°F. (37°C.) was recorded, only 3·4°F. below the critical zone for both species of 102°–106°F. (38·9°–41·1°C.). It was suggested that partial clearing might raise the temperature in the microclimates and so destroy both species of tsetse (Nash 1936 *b*). Partial clearing has obviously failed to act in this fashion, as *G. morsitans* still survived when *G. tachinoides* was exterminated, yet the critical temperature zone for both species is practically the same (Nash 1935 and 1936 *b*). It has recently been found that even after partial clearing cooler microclimates exist at ground-level inside hollow trees and in deep clefts running into the trunk. In each island three such sites were kept under observation from March to May 1939; the highest temperatures recorded were only 87·0°F. (30·6°C.) in the Experimental Forest Island, and 90·5°F. (32·5°C.) in the Control; the absolute maxima at 4 feet in the Stevenson screens were 107·0°F. (41·7°C.) and 102·5°F. (39·2°C.) respectively. In this year's investigation a miniature wooden table with legs three inches high was placed over the bulb of each thermometer so as to prevent any possibility of a transitory beam of sunlight influencing the reading; possibly the tables enabled pockets of cool air to collect, but even so there can be no doubt that very cool microclimates exist upon which partial clearing has no effect. *G. morsitans* were observed resting in one of the hollow trees in the heat of the day.

It may be concluded that *G. tachinoides* was definitely not exterminated by the temperature reaching the upper fatal limit. Nor is it likely that the mean temperature was *dangerously* high, as Buxton & Lewis (1934) did most of their laboratory experiments at a constant temperature of 86°F. (30°C.), and the mean monthly temperature at four feet in the Experimental Forest Island was only 88·5°F. for April 1939—the hottest month; at ground-level the mean temperature would have been considerably less.

With regard to evaporation, it may have been noticed in Table I that whereas the difference in the evaporation rates in the two islands was increased by thinning the seedling ebonies, the actual degree of evaporation was if anything less than in the previous year, yet the effect on the fly in the partly cleared island was far greater. It is suggested that the clumps of very small seedling ebonies formed a relatively extensive ecoclimate and that the evaporation amongst the leaves near ground-level was much less than that recorded by the writer at 5 inches in an open part of the forest floor. The ecoclimate may have provided this thicket-loving species of tsetse with a permanent shelter in which it could just survive the abnormally high evaporation, but when this shelter was destroyed in the following year the extermination of the species was assured. Admittedly this is only a speculation, but *G. tachinoides* does live at a " lower level " than *G. morsitans*; it attacks the ankles, not the legs or back; on repletion it flies off on to the ground or rests on a tiny blade of grass, not on to a tree-trunk some feet above the ground.

The writer does not believe that *G. morsitans* is unaffected by high evaporation; on the contrary, he has previously shown that rising evaporation is related to a great decrease in the *G. morsitans* population of the fly-belt *as a whole* (Nash 1933, 1937). However, he does believe that *G. morsitans* is far more resistant to high evaporation rates, and that although excessive evaporation may reduce its density, it cannot effect its extermination. Experience throughout Africa has shown that clearings against *G. morsitans* must be ruthless to be effective. The probable reason is that by felling every tree all microclimates are destroyed and the flies are killed by the sun temperature; but if trees are spared, the flies can find protection from temperature and are merely reduced in density by high evaporation.

Practical Application of Partial Clearing.

It is obvious from the experimental work described that the amount of clearing required to exterminate *G. tachinoides* will depend upon the severity of the local climate. Thus at Gadau, where the mean annual rainfall is 31 inches, it is possible to spare all large trees, providing the thicket and some of the seedlings are removed; but further south near Zaria, which has an average rainfall of 44 inches, it is also necessary to remove all low-branching shade trees.

Partial clearing has been tried on a large scale at Anchau, near Zaria, where 207 miles of stream have been cleared at an average cost of £10 3s. 2d. a mile, or 609 man-days. In this area *G. tachinoides* infests the narrow belt of riverine vegetation which lines the banks of all the water-courses. The partial clearing of this vegetation has proved sufficient to *exterminate* the tsetse. Not only is this method cheaper than ordinary clearing, but it also enables useful timber to be spared and provides high shade under which grazing cattle can rest in the heat of the day. To prevent wet season reinfestation from the point where the partial clearing stops, it is essential to fell the last stretch ruthlessly and to pile and burn it. There should be a mile between the starting and end points of the barrier, so that if the stream winds much, considerably more than a mile of stream-bank will have to be ruthlessly cleared. Whole stream systems have been successfully dealt with in this fashion, but the officer in charge must inspect every yard of the work himself to see that the headmen have not left uncleared some diminutive, unmapped tributary or patch of thicket. Such omissions frequently occur, enabling *G. tachinoides* to survive behind the barrier. Partial clearing has recently been tried against *G. palpalis* at the northern limits of its range ; the present indications are that the method will succeed.

Another type of partial clearing is in the process of being evolved and is called " spot clearing." In hilly country where the fall is considerable many miles of the upper reaches of a stream-system are found in the late dry season to be completely waterless and fly-free, with the exception of a few spots where a pool of water, wet sand, or extremely dense vegetation, produces a cool ecoclimate in which tsetses can survive the hot, dry months. These sanctuaries are located by a fly survey, and are then cleared in the following dry season. A barrier of ruthless clearing is inserted at the point where permanent water starts in the stream ; the barrier should be about two miles in length. Should the method prove satisfactory great savings could be made, but hitherto it has only been tried on one stream-system. Only 7½ miles were cleared out of a total of 23, but unfortunately the work was completed so late in the dry season that immediate extermination was not achieved. During the ensuing rains an average of only 9 flies were caught in the 23 miles ; but the rains were exceptionally heavy, and in the following late dry season water remained in many uncleared places where it had not done so before, with the result that extermination was again not achieved and density rose in the following rains to 37 flies per 23 miles. The results are inconclusive, because the clearing should have been carried out early in the dry season, and because there is still a chance that extermination will take place as this year's rains have been normal.

As yet there has been no tendency for streams to dry up after clearing ; if anything, they now contain more water. Admittedly increased exposure to sun and wind must increase the amount of water lost by evaporation, but this loss is probably less than the amount of water conserved by destroying dense masses of transpiring riverine vegetation. In an experiment in Tanganyika, Staples (1934) showed that the loss of water on a hot, dry day was less from a cleared than from an uncleared stream.

In small, isolated, protective clearings around village water-holes and at places where trade routes cross streams, it is essential that the clearing be utterly ruthless. Three hundred yards on each side of such places is found sufficient for *G. tachinoides*, but 400 yards is required for *G. palpalis*. These distances prove inadequate for permanently flowing *rivers*, where the moister and cooler conditions enable tsetse to cross longer barriers in the rains. Where *G. morsitans* occurs it is wiser to make no attempt at clearing, unless large sums of money are available and the density of population is such that many will benefit.

Summary.

1. The removal of the thicket windbreak from around a residual forest island considerably alters its climate and intensifies the rigours of the dry season. The evaporation rate becomes much higher ; appreciable increases are caused in the atmospheric diurnal temperature, but are more pronounced in the soil temperature. The island becomes slightly colder at night.

2. The thinning out of the seedlings on the forest floor accentuates these climatic differences, especially evaporation near the soil surface.

3. The enhanced severity of the climate leads to the virtual extermination of *G. tachinoides*. From the end of the rains the fly population steadily decreases with rising evaporation ; pupal mortality starts increasing and pupal density decreasing, until breeding practically stops at the end of the cold season and ceases altogether in the hot weather. By the late dry season the virtual extermination of the species is complete.

4. Increased evaporation is considered to be much more important than temperature in bringing about this destruction.

5. The successful re-colonisation of the forest island in the rains proves beyond doubt that wet season climatic conditions are much more favourable to tsetse than dry season conditions.

6. *G. morsitans* continues to concentrate in the forest island, but fails to produce the dry season local increase in population. It is believed that immigration just equalises the increasing death rate and so prevents the population from decreasing.

7. Although adversely affected by high evaporation, *G. morsitans* is much more resistant to it than *G. tachinoides* ; possibly *G. tachinoides* loses water more readily than *G. morsitans* at the same evaporation rate. *G. morsitans* manages to avoid lethal, mid-day, shade temperatures by resting at ground-level in hollow trees and crevices between roots.

8. Throughout Africa it has been found that clearing against *G. morsitans* must be ruthless to be completely effective. It is suggested that the felling of every tree destroys all microclimates, enabling the fly to be killed by sun temperature ; but if trees are spared the fly can find protection from temperature, and is merely reduced in numbers by high evaporation.

9. As a result of this experiment, partial clearing has been carried out against *G. tachinoides* on a very large scale and has been found to lead to complete extermination. It is also likely to prove effective against *G. palpalis* at the drier end of this species' range.

10. The amount of vegetation spared must depend upon the local climate ; the higher the dry season evaporation rate, the less clearing will be required.

11. In hilly country where the upper reaches of the stream fail to hold water except in the rains, a late dry season fly survey will locate concentration haunts around occasional pools. If these are cleared, the destruction of the sanctuaries may lead to extermination, provided that a ruthless barrier clearing is made lower down to prevent wet season re-infestation.

12. In small and isolated protective clearings, 300 yards of *ruthless* felling are required on each side of the ford or village drinking-hole ; 400 yards are required for *G. palpalis*. On permanently flowing rivers, these distances prove inadequate in the rains. Clearing against *G. morsitans* must be both ruthless and very extensive, and is inadvisable in Nigeria unless warranted by a large population and abundant funds.

Acknowledgments.

The writer is grateful to Dr. H. M. O. Lester, O.B.E., Deputy Director, Nigerian Sleeping Sickness Service, for facilitating the investigation, and to Dr. R. Harding for keeping an eye on the work in the writer's absence. Mention must be made of the complete reliability of Mallam Ibrahim who has been directly in charge of the routine observations. Finally, the writer is indebted to the Sleeping Sickness Control Officers who have been superintending the large-scale application of partial clearing as an anti-tsetse measure in the Anchau settlement scheme.

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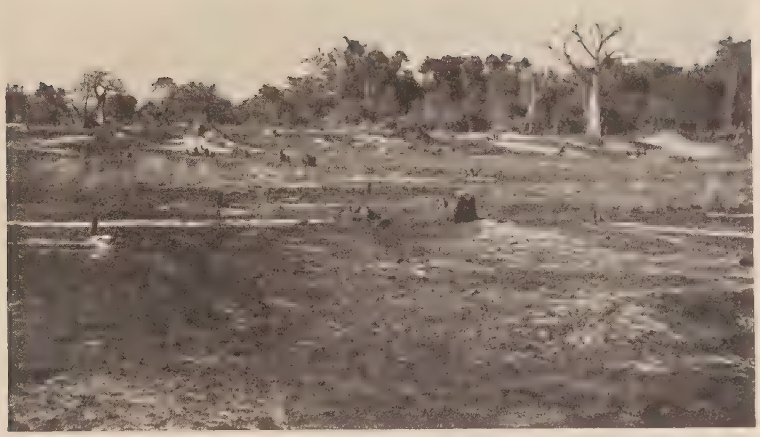

Fig. 1. Looking from the Experimental Forest Island across the 330 yard barrier to the Control.

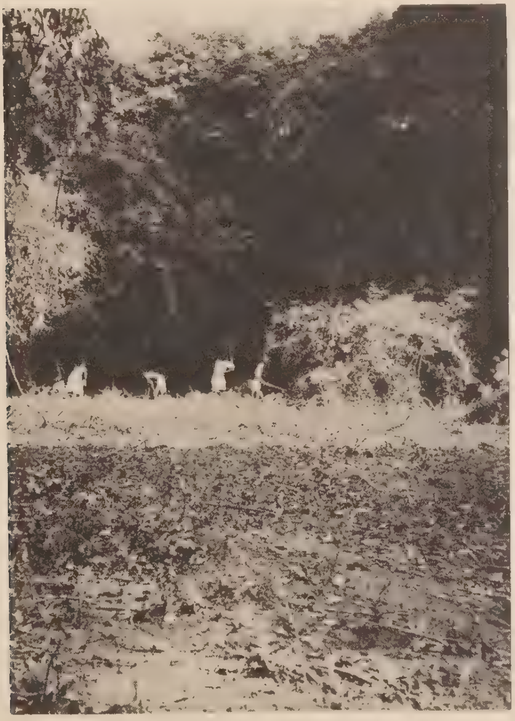

Fig. 2. The true forest is revealed as the last of the thicket is removed. (The whole foreground was originally thicket).

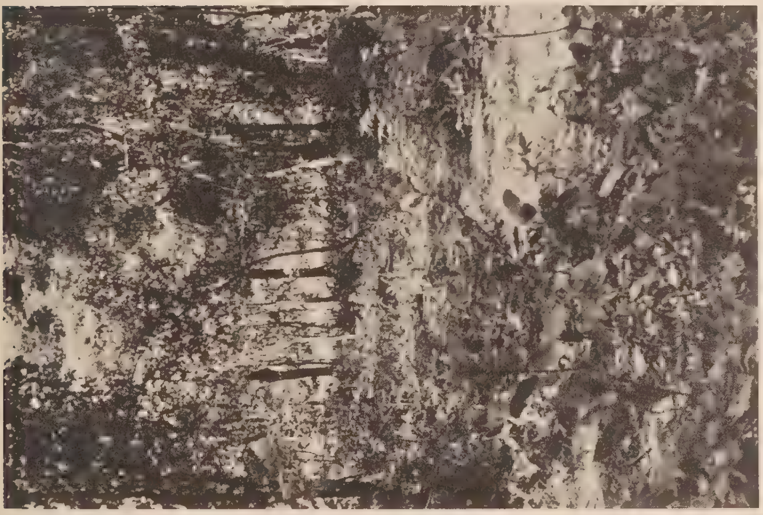

Fig. 1. After removal of thicket windbreak (Period II). Note the clump of seedling ebonies in the foreground.

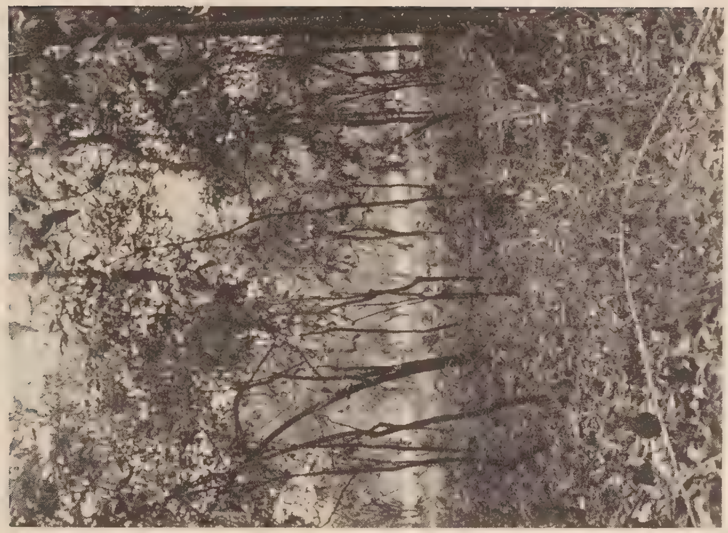

Fig. 2. After thinning of seedling ebonies (Period III).

Looking from inside the Experimental Island out to the open woodland which is visible now that the peripheral thicket has been removed.

TWO NEW PESTS OF APPLE AND BLACK CURRANT.

By H. F. Barnes, M.A., Ph.D.,
Rothamsted Experimental Station.

(Plate III.)

To be forewarned is to be forearmed and it is for this reason that the following information has been written concerning a gall midge which has recently been reported attacking apple blossom in Japan and another gall midge which attacks black currant flowers in Finland. Both prevent the formation of fruit. It is possible that either or both of these pests may appear in other countries.

The Apple Blossom Midge (*Contarinia mali*, Barnes).

This species was first discovered in 1926 in the Nagano Prefecture, Japan. Mr. C. Tanabe (1936) has recently studied its biology and the following information is taken from his papers. It has one generation a year, the adults emerging in late March or early April. The male lives 3–10 days and the females 4–27, the latter beginning oviposition 3–10 days after emergence. The eggs are laid in the flower-buds of apple and the larvae hatch in 12–15 days. About 45 larvae are found in each flower-bud and are fully fed in about 15 days. The infested buds which are swollen remain closed, the petals becoming thick and spotted with a dark pink. Naturally, the fruit does not set. The larvae leave the buds for the top inch or so of the soil towards the end of May. The prepupal stage lasts about 140 days, while pupation takes place in late September and lasts about 190 days. Hand-picking the infested buds has been recommended as a control. In addition intensive cultivation for several weeks at the end of May and in June and again in the spring might be suggested, as might also allowing poultry free range under infested trees at the same periods of the year.

This midge was only described (Barnes, 1939) as recently as 1939 from dead specimens sent to England by Dr. H. Yuasa, of the Imperial Agricultural Experiment Station, Nisigahara, Tokyo. Some cotypes have been returned to Tokyo and others retained in the Barnes collection. The species is a large *Contarinia*, very similar to the pear midge (*C. pyrivora*, Riley). The main points of difference are as follows :—The apple blossom midges are slightly smaller in general size ; their wings are slightly narrower ; in the male, and to a lesser degree in the female, the distal prolongation of the terminal flagellar segment of the antennae is not nearly so pronounced as in the pear midge ; in the female the necks of the basal flagellar segments of the antennae are more transverse and much shorter than in the equivalent segments of the pear midge ; and in the latter species the first flagellar segment in the female is longer than in the apple blossom midge.

As this species spends part of its life-history in the soil it is possible that it may be carried out of Japan into such countries as Canada and subsequently the British Isles.

The Black Currant Flower Midge (*Dasyneura ribis*, sp. n.).

A gall midge attacking the flowers of black currant has been recorded on several occasions from Finland. Up to the present this midge has not been reported from any other country. The writer is indebted to Dr. Niilo A. Vappula for translations of various published notes on this species as well as for unpublished notes and actual specimens. The first published note on this midge occurred in Forsius' (1922) list of CECIDOMYIDAE found in Finland. This author stated that a *Diplosis* sp. living in the flowers of black currant was on record from Nylandia and Tavastia australis in South Finland and that its behaviour resembled that of *Contarinia ribis* (Kieffer) de Meijere. Linnaniemi (1935) wrote that Mr. Y. Hukkinen observed in 1920 in Kuhmoinen (a community in Tavastia australis) galled flowers on black currants caused by maggots of a gall midge, the galls being found up to 5–10 per cent. on both cultivated bushes and wild ones. In 1920 he also found the galls in several localities in Nylandia. In 1923 it was again found in Tavastia australis. Later, Hukkinen & Vappula (1935) wrote of it in Helsinginmlk in Nylandia as follows :—Galled flowers were very abundant in 1924, the corolla of which had become enlarged and swollen ; the flowers mostly failed to open and develop further. It was also present in Tavastia australis in 1924. In 1925 it was rather abundant in Savonia australis, which lies to the east of Tavastia australis. In 1927 it was reported for the first time from Tavastia borealis, Hukkinen, Listo & Vappula (1936) stating that from 80–90 per cent. of the flowers on one bush were galled. From a map of its distribution sent by Dr. Vappula it has also occurred in Ostrobottnia borealis on the borders of Finland and Sweden.

In all the above publications, with the exception of the first, this midge has been referred to as *Contarinia ribis* (Kieffer) de Meijere, the gooseberry flower midge. In June 1938 Dr. Vappula sent the writer galled black currant flowers (Plate III, fig. 2) containing numerous orange-red and white larvae. The former were evidently those of a *Dasyneura* gall midge, while the latter were those of an ectoparasite (Cecid. 3683–8). An internal parasite was also present in small numbers (Cecid. 3682). A successful attempt was made to rear adult midges from this material. Emergence started on 19th April 1939, and continued until 13th May. This proved that the species involved belonged to the genus *Dasyneura*, and it is described below as *D. ribis*, sp. n.

Dasyneura ribis, sp. n.

Male. Length about 1·5 mm. Antennae : 2+13–15, of typical *Dasyneura* structure, neck of 1st flagellar segment almost quadrate ; neck of 3rd about three times as long as wide, slightly shorter than the node ; neck of 10th flagellar segment four to five times as long as wide and about the same length as the node. Palpi : proximal segment about quadrate ; second nearly twice as long as first and about twice as long as wide ; third slightly longer, about three times as long as wide ; distal segment slightly longer, about four times as long as wide. Wings : 3rd vein reaching margin just before apex. Legs scaled, claws with well developed basal tooth, empodium about as long as claws. Genitalia : basal clasp segment slightly more than twice as long as wide, with long setae ; distal clasp segment rather broad, short ; dorsal lamella, each lobe large, rather broad, rounded ; ventral lamella broad, wide shallow emargination, each lobe narrow ; harpes prominent.

Cotypes : Cecid. 3942–5 and 3987–90 in the Barnes collection.

Female. Length about 2 mm. Antennae : 2+11–14 ; necks of flagellar segments practically absent, transverse. Abdomen with bands of dark scales on tergites, pale red in life, reminiscent of *D. tetensi*, Rübsaamen, deeper red when mounted in balsam within a few days of killing. Ovipositor normal pocket-shaped. Otherwise about as in male.

Cotypes : Cecid. 3946–51 and 3991–7 in the Barnes collection.

Pupa. Cecid. 3952.

Larva. Length 2½–3 mm. when full-grown, orange-red, bifid anchor process, lobes pointed, each lobe and emargination co-equal.

Cecid. 3677–83.

Although the larvae were Finnish, the adults emerged at the right time in England* to enable them to infest black currant. This supports the experience of the writer that gall midge larvae received from various localities one year and kept over winter at Harpenden adjust themselves as regards emergence period to that of their host-plant in the new locality. On the other hand, gall midge larvae which emerge the same season do not so adjust themselves to the new conditions but emerge on the dates they would have done in their previous locality. For this reason if larvae of *D. ribis* did happen to get transported to England there is every possibility that the midge would become established there.

Female midges were given the opportunity of infesting black currant on 21st April 1939. They at once started ovipositing in the smaller flower-buds. The larger flower-buds were avoided. Oviposition continued all day. Several eggs were laid in each bud, the ovipositor being inserted between the sepals. By 10th May the galls were distinctly visible (Plate III, fig. 1), the flowers remaining unopened and swollen. On 20th May the larvae, orange-red in colour, were full-grown and started leaving the galls for the soil, where they remained until the following spring. Up to 16 larvae occurred in a single flower. No emergence of adults took place up to the second week in December 1939. It is thus apparent that there is only one generation a year.

Dr. Vappula wrote (20.iv.38) that in Finland the midge has been only observed on black currant, with one exception in which it was found by him in 1936 on *Ribes alpinum*. In no case has it been found on gooseberry or red currant. In the writer's limited experience, when the adults started emerging the gooseberry and red currant flowers were well past the bud stage and so unsuitable for oviposition. This difference in time of flowering of the various *Ribes* would account for the fact that the midge has not been found attacking gooseberry or red currant. Similarly, *Contarinia ribis* (Kieffer) de Meijere, which also lives in unopened flower buds, is only reported from gooseberry which flowers before red or black currant.

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* All this work was carried out in an insect-proof glasshouse at Rothamsted Experimental Station, Harpenden, extreme precautions being taken to prevent any midges escaping.

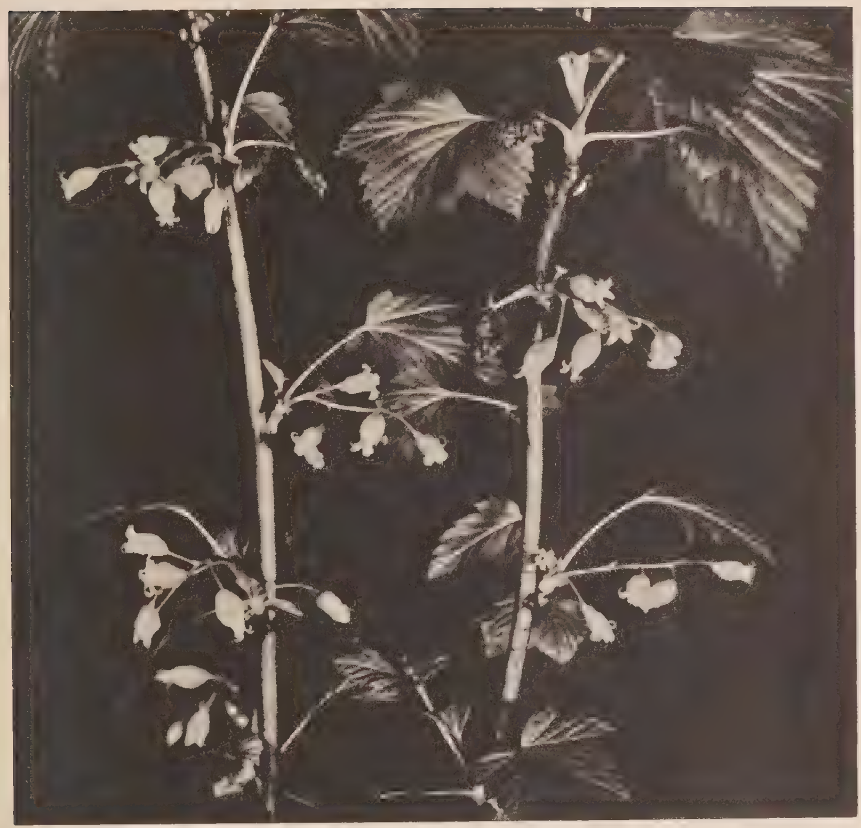

Fig. 1. Black Currant flowers attacked by *Dasyneura ribis*, sp.n., about three weeks after oviposition and about a week before the larvae were full grown.

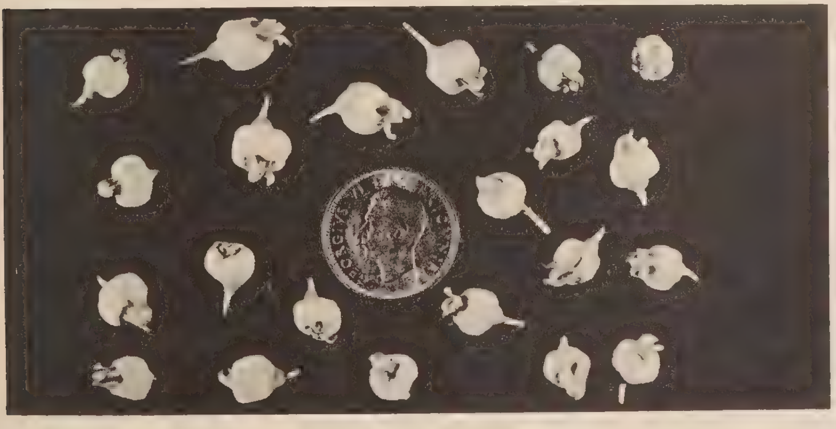

Fig. 2. Flowers of Black Currant infested with larvae of *Dasyneura ribis*, sp.n. (Photographed with a sixpence to show size).

INVESTIGATIONS ON THE COTTON BOLLWORM, *HELIOTHIS ARMIGERA*, HÜBN. (*OBSOLETA*, FABR.).

PART II. THE INCIDENCE OF PARASITES IN QUANTITATIVE RELATION TO BOLLWORM POPULATIONS IN SOUTH AFRICA.*

By F. S. PARSONS, B.Sc.Agr., F.R.E.S.

The earlier years of these investigations were devoted to extensive field work on the value of the egg parasites, *Trichogramma luteum*, Gir., and *Telenomus* (*Phanurus*) *ullyetti*, Nixon, as agents for the control of *Heliothis armigera*. As reported (Parsons & Ullyett)[1] attempts to exploit *Trichogramma* were abandoned in view of the unpromising results. But, by means of the quantitative methods for the survey of bollworm incidence in use at Barberton,[2, 3, 4] which were inaugurated while the above parasite investigations were in progress, provision was made to continue records on the incidence of *Trichogramma* and *Telenomus* and to observe the occurrence of the other indigenous parasites.

Part 1[3] of the present series has dealt with the annual march of bollworm incidence and the definition of a " Bollworm Year " from June to May in which a recurring periodicity of the main features is exemplified. The object of the present paper is to present the information obtained on the parasites and to view it in relation to the background afforded by the data in Part I. The work has been largely of a phenological character and the results have been obtained from continuous routine observations carried out with the purpose of assessing the individual and combined effect of the parasites in the limitation of bollworm populations.

As described in Part I, the pursuit of information on the incidence of bollworm has been continuous and inclusive with regard to the complexes of bollworm food-plants produced under the climatic and agricultural circumstances of the years under review. Observations on samples of the egg and larval populations drawn over a long period from all the food-plant assemblies have indicated parasite associations of a seasonal and crop nature that are stated in the text. Particulars of the levels of parasitism are given and their importance discussed with reference only to the bollworm problem in the areas of record. Studies of the parasites have not been attempted.

Methods of Studying Egg Parasitism.

Quoting from the investigations of Parsons & Ullyett[1] on the value of released *Trichogramma*, " It is clear that to procure a guide to the degree of parasitism, eggs must be left where laid and marked to observe events. Apart from the eggs, parasitized or otherwise, which are destroyed on the plant, any sample of undated bollworm eggs *collected* from plants contains eggs ranging in size from a few hours to several days, with consequent differences in the length of time of exposure to parasitism. Bollworm eggs that are mainly 48–60 hours old may be parasitized to the extent of 70 per cent., whereas a collection composed largely of eggs laid in the previous 24 hours may contain very few parasitized eggs ; yet it would seem that calculations of parasitism are based frequently on evidence obtained from small and discontinouous collections. An increase in the parasitism of the total ' parasitizable ' eggs (fertile eggs less than 60 hours old) present at any period in the course of oviposition does not necessarily mean an augmented parasitism amongst the eggs destined to escape destruction by some predatory or other agency. Hence estimates of effective parasitism should be based only on parasitized eggs in the surviving or active fraction, and before significance can be attached to these estimates, values for them must be sought in comparative computations of resulting larvae." It has not been possible to adhere to these measures in the routine survey work, but a compromise was effected as follows :—

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* Contribution from the Cotton Insect Pest Control Section of the Cotton Experiment Station, Barberton, Transvaal, South Africa.

Eggs were collected weekly or twice-weekly over 7 years from the cultivated crops and wild food-plants in the sequence of their attraction to the moth. The plants from which eggs were removed were duplicate samples of those utilized for egg counts upon which estimates of the egg population were based according to methods of sampling and calculation and for purposes discussed in Part I. On each collection date eggs were drawn from a separate sample of plants in order to avoid undue disturbance of the egg population at the points of record. Eggs were collected individually in gelatine capsules for observation in the laboratory. Eggs which, according to their incubation periods, were unlikely to have been exposed for at least 24 hours to parasite and other destructive action, were excluded from the sample. Infertile eggs were also withdrawn. In the remainder (termed the " active " fraction) the parasitized eggs were noted readily, and the identity of the parasite was recorded on emergence. The data so obtained provided a running index of the degrees of parasitism attributable to *Trichogramma* and *Telenomus*, and some information has been won on the biology of the parasites at different seasons of the year.

The percentages of parasitism obtained by this method are generally lower than the figures found from eggs marked *in situ* on field crops. In the field the situation is affected by a predilection of the predators, *Tryphleps* sp. and *Chrysopa* sp., for unparasitized eggs, and there is also evidence that eggs containing parasites advanced in development are less readily washed off by rain.

Owing mainly to difficulties in reconciling times of exposure with predatory, parasitic and other actions, comparisons between the data from eggs collected and left undisturbed in the same crop cannot be drawn very closely. But in several tests preceding the reported investigations on released *Trichogramma*, the parasitism determined on the active fraction of eggs *in situ* on maize ranged from 9 to 20 per cent. higher than the estimates formed from eggs collected in the same crops. Comparisons of this nature have not been made in other types of crop and in wild food-plant situations where habits of plant growth, egg-laying sites and the constitution of the insect community are among the diverse factors.

The information and conclusions presented in this paper are drawn from data collected in the environs of Barberton in the Transvaal. Conformable results have been found from similar, but less intensive, work in Natal and Swaziland.

Extensive samples of eggs have been collected from time to time at various other points in the Transvaal and also in Portuguese East Africa with a view to ascertaining whether other egg parasites of *Heliothis* were present in these regions ; with the exception of one doubtful record, only *Trichogramma luteum* (3 races) and *Telenomus ullyetti* have been encountered.

Annual Course of Egg Parasitism.

The estimated percentages of the " active " egg populations parasitized between June 1934 and March 1938 are given graphically in fig. 1. The figures for the period August 1937 to March 1938 are taken from data associated with analyses of egg and larval mortality in the principal cultivated crops where eggs *were* marked *in situ* ; they are not, therefore, quite comparable with the estimates of the previous years. In this season continuous records were dispensed with and, as illustrated, sampling

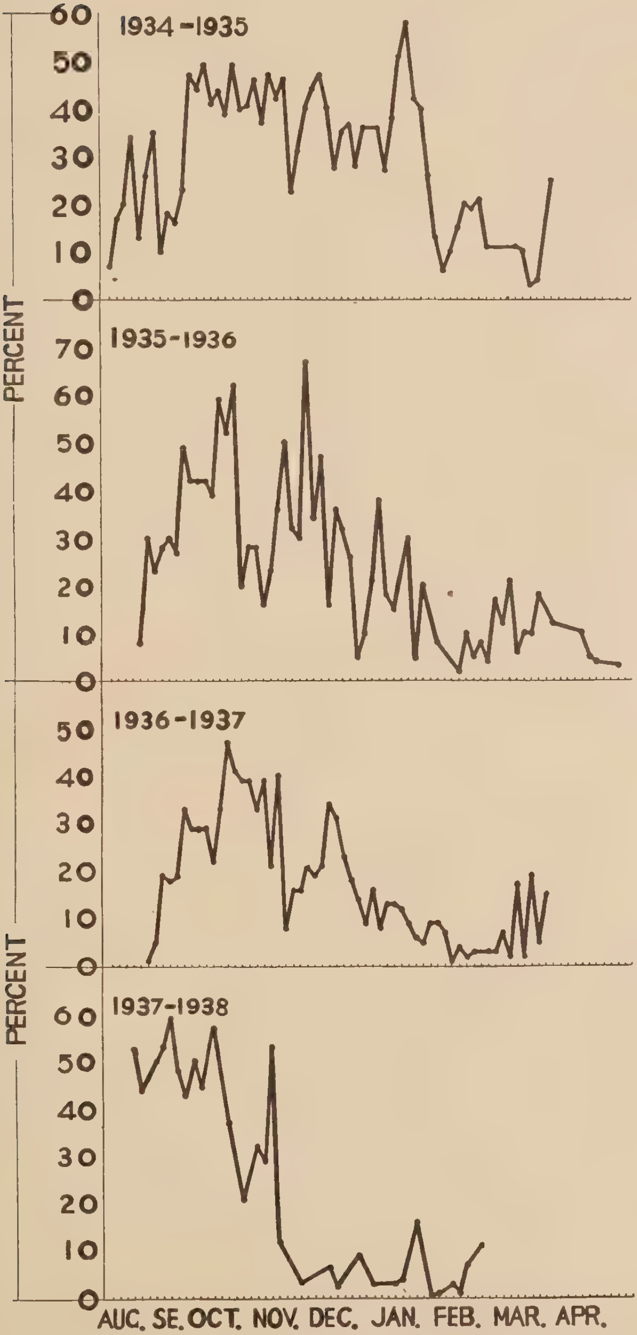

Fig. 1. The annual course of egg parasitism.

began when parasitism was already at a high level. The sudden drop in parasitism between mid-November and the end of December 1937, as compared with the earlier years, is due to the cessation of recording in areas of wild food-plants, where bollworm activity at this time of year is largely concentrated.

It is evident from fig. 1 that in each year the highest levels of egg parasitism were experienced and maintained between August and the end of December. Later (summer) incidence was low, irregularly. This was found also in estimates obtained by Parsons & Ullyett between 1931 and 1934, when the egg-marking method was employed generally : thus a similar course of egg parasitism has been recorded in seven successive years. The exception indicated in January 1935 is due to parasitism over a brief period by *Trichogramma* in egg populations where the computed " active " fraction was an unusually low proportion of the collected egg samples (fig. 4) ; if expressed on total eggs, the percentages would be reduced to about one-half of the figures illustrated, whereas ordinarily (fig. 4) the disparity between estimates based on eggs collected and the pertinent " active " fraction would be decidedly less.

The annual courses of egg parasitism and of bollworm incidence (the latter as evinced by oviposition data) may be viewed in relation in figs. 1 and 2 ; fig. 2 is reproduced from Part I. The period August to November is one of surpassing bollworm activity in a number of winter-irrigated crops, and this falls within the period of highest egg parasitism. The graphs portraying bollworm incidence do not include oviposition on wild food-plants owing to difficulties in expressing the situation in comparable terms of eggs-per-acre. But, as intimated earlier, a peak of laying occurs on the wild food-plants in December and, except in 1937, egg populations there have been sampled for evidence of parasite activity. Particulars of the distribution of egg parasitism with respect to wild food-plants are given in Tables II and III with comments.

Comparisons in figs. 1 and 2 of the oviposition on cotton and associated summer crops (which are grown from December–January to the end of the " Bollworm Year " in May) and the depiction of summer parasitism emphasize the generally low levels of the latter.

Individual Parasitism by Telenomus and Trichogramma.

The graphs in fig. 1 present continuous indices of the combined activity of the two parasites. For the greatest part of the year, however, both parasites are not present in quantity at the same time. The recurring seasonal aspect of their incidence is illustrated in fig. 3, including data for 1932 and 1933. It is evident from this figure that *Telenomus* predominates greatly from August to early December and is associated mainly, therefore, with the bollworm in the winter-irrigated crops, viz., tomato, pea, bean and other vegetable crops. In four of the six years *Trichogramma* did not appear until October, but had exceeded *Telenomus* by December, and thereafter to the end of the summer season practically all of the parasitism was due to *Trichogramma* ; this parasite is associated mainly with the egg populations on rain-grown cotton, maize and other summer crops. It is only during November and December that the parasites are active together in quantity, their activity being centred largely in the colonies of wild food-plants, which serve as the principal bollworm breeding grounds during this period between the cessation of winter vegetable-growing and the appearance of summer crops. Estimates of their relative activity are given in Table III.

When investigating the value of released *Trichogramma* (*l. c.*) attempts at establishment between August and October met with little or no success, and appreciable results were not apparent before the resumption of natural parasitism by *Trichogramma*. The seasonal activity of this parasite appeared to be governed by climatic factors and, although the subject was not studied closely, observations in

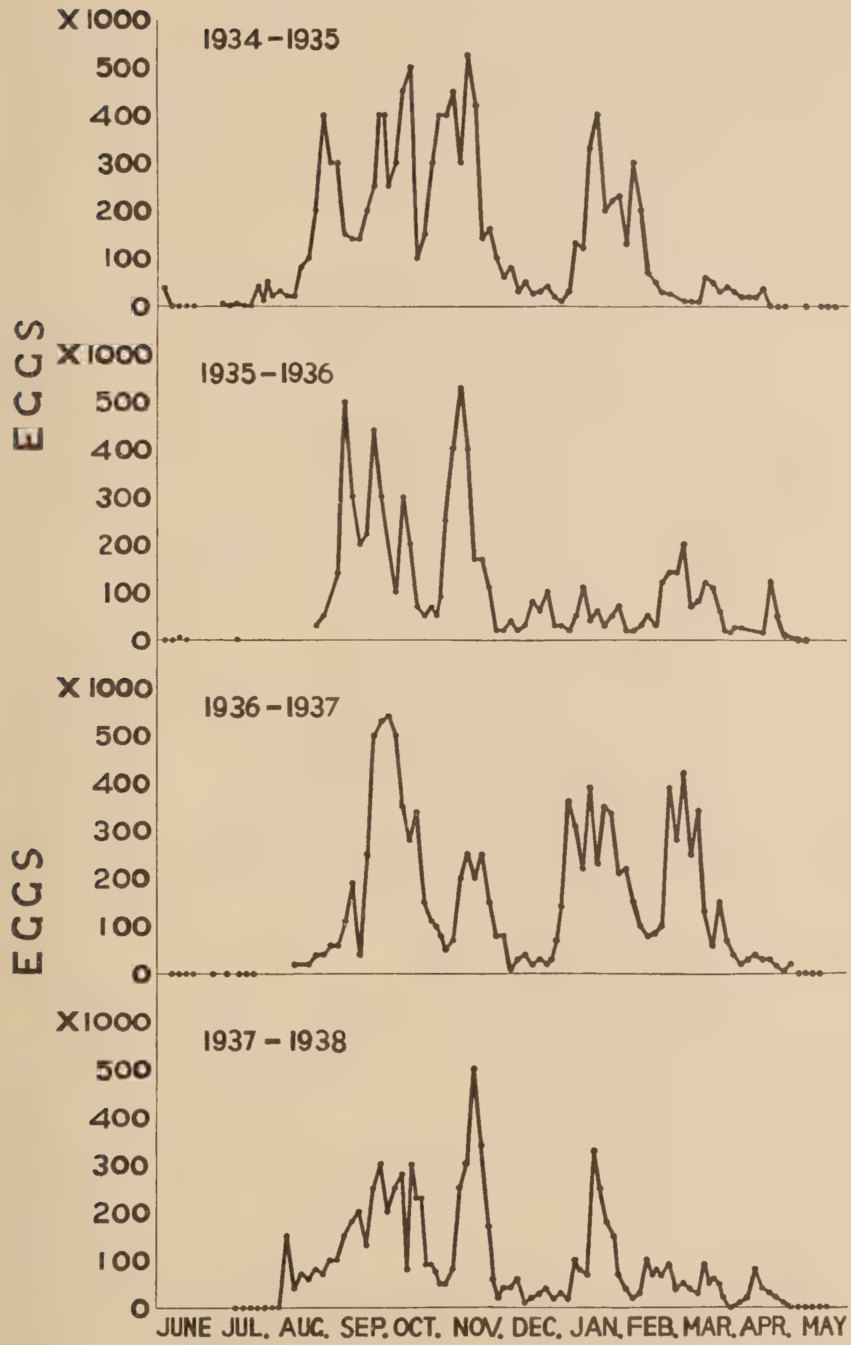

Fig. 2. The annual course of bollworm incidence.

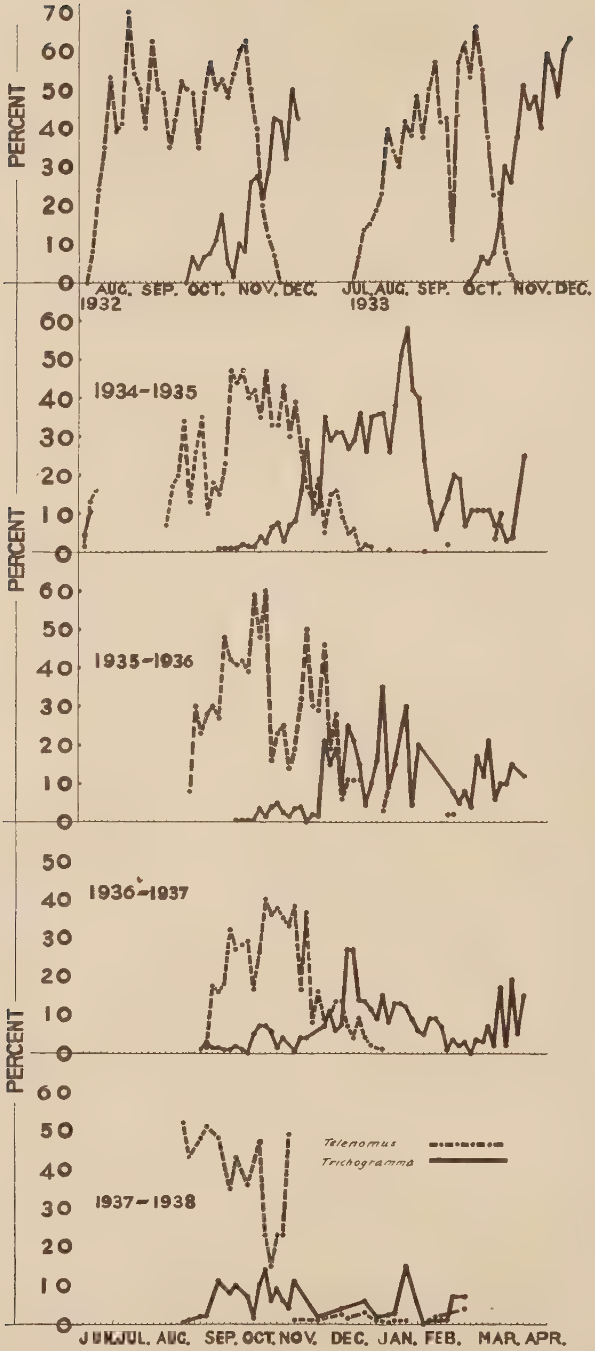

Fig. 3. Individual parasitism by *Telenomus ullyetti* and *Trichogramma luteum.*

the course of insectary and laboratory work supported this view. The presence of *Trichogramma*, though in relatively small numbers, during the vegetable-growing seasons of 1936 and 1937 is attributed to the fact that these winter seasons were milder than usual, particularly 1937. Jones[6] has found that low humidity, such as generally obtains here in the dry season, is a determining factor in the incidence of *Trichogramma* in Rhodesia. He also found that the temperatures and humidity of the Mazoe Valley in Rhodesia, which are not dissimilar to those of Barberton, restrict *Telenomus* during the summer season.

Crop-Bollworm-Parasite Association.

The percentages of parasitism illustrated in figs. 1 and 3 are based on the total of " active " eggs from all samples wherever taken on each date of collection. But it was observed early that the levels of parasitism in certain crops were commonly higher than in others, and examination of all the evidence enables the specification of crop-bollworm-parasite relationships as follow :—

Only the crops grown in considerable acreages need be considered here. The mean percentages of the bollworm eggs parasitized per crop per annum are given in Table I. The data for each year have been taken from many examples of each of the crops.

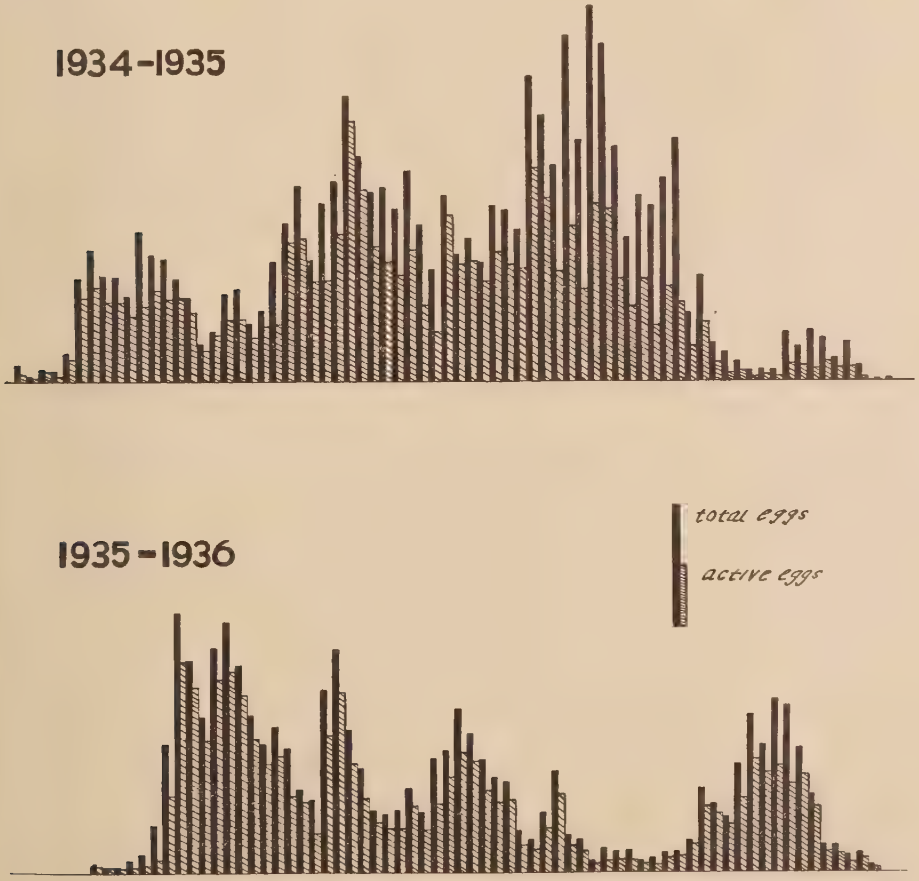

Fig. 4. Proportions of " active " eggs in eggs collected.

TABLE I.

Egg Parasitism in relation to Food-Plants of Heliothis armigera : *number of " active " Eggs and Percentages Parasitized.*

Year	Tomato		Pea		Marrow		Bean		Cucumber		Wild food-plants		Maize		Cotton	
	Eggs	%	Eggs	%	Eggs	%	Eggs	%	Eggs	%	Eggs	%	Eggs	%	Eggs	%
1934/35 ...	1651	69	1545	5	1000	48	290	25	409	45	1235	31	3155	31	4957	24
1935 36 ...	823	73	1537	6	723	51	696	33	370	45	2115	38	2771	11	300	3
1936 37 ...	842	60	2489	9	753	36	502	11	449	59	1651	29	2049	15	2814	6
1937/38 ...	986	73	1529	21	658	31	801	38	243	43	—	—	2671	15	350	2
Means ...	—	69	—	10	—	41	—	27	—	48	—	33	—	18	—	9
Total eggs	4302	—	7100	—	3134	—	2289	—	1471	—	5001	—	10646	—	8421	—

Analysis of variance of the data in Table I shows that the differences between years in the levels of parasitism as a whole are not significant. But in any one year, a difference of 17·6 between the parasitism for any two crops is significant at the $P = \cdot 05$ level. On the means per crop for the four years, a difference of 12·63 is also significant at the ·05 level. It is thus evident that *Telenomus* (to which most of the winter season parasitism may be attributed) exhibits greatest activity in the tomato, marrow and cucumber crops, especially tomatoes. Before accepting the implication of these data it was necessary to determine whether there are differences between egg populations on the various crops with regard to the proportion of infertile eggs, as withdrawn from the collected samples ; given equal parasite activity and equal access to eggs, a persistently higher degree of egg infertility in the eggs from one crop as compared with those from another would, of course, alter the bases of comparison. This question is linked with the fact that *Heliothis* moths of both sexes require food before fertilization ensues, food being taken mainly from floral nectaries. It has been established here that *Heliothis armigera*, with few exceptions, oviposits on food-plants coincidently with their flowering ; the presence or absence of nectaries, quantity, and, perhaps, quality of nectar, are, therefore, points for consideration. Actually, significant differences have not been found between different types of crop in the proportions of infertile eggs over the whole of the eggs collected per crop. In this connexion it is of interest that of some 40,000 collected eggs, 20·5 per cent. were infertile, and that insectary observations of the infertility in 52,000 eggs from fed and paired females, ovipositing normally, gave a mean of 19 per cent. The coefficients of variability were 32·4 and 27·50 per cent., respectively. The field and insectary conditions noted are consistent with observations at Barberton on the mechanism of egg delivery from fed and fertilized *Heliothis* moths[5].

According to estimates of eggs-per-unit-area, the tomato and marrow crops are favoured for oviposition by the moth, thus the higher parasitism takes place in the commonly larger egg population on them. Oviposition on cucumbers is not so extensive but compares in magnitude with that on peas and beans. It is suggested that the higher parasitism of eggs on the tomato, marrow and cucumber crops may result from the fact that, in these cases, the moth lays mainly on and around the flowers ; the eggs are concentrated and easy of access. The plants in question have an open habit and do not encroach as in the more closely planted pea and bean crops, and this probably also facilitates discovery of the host eggs. Possibly the closer growth of certain crops deters penetration by the parasites, which are positively phototropic, and the higher parasitism amongst the plants of open habit and stand may be due to larger parasite populations drawn thereto and developed therein in response to these crop characteristics. The smaller, smoother plant area and very open nature of the tomato plant are suggested as factors contributing to the particularly high levels of parasitism recorded in eggs from this crop ; another factor—duration of flowering and oviposition—is discussed below.

TABLE II.

Serial Records of Percentage Egg Parasitism.

Dates	Tomato				Marrow				Cucumber				Wild food-plants		
	1934	1935	1936	1937	1934	1935	1936	1937	1934	1935	1936	1937	1934	1935	1936
July 31 ...	48	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug. 7 ...	53	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 10 ...	67	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 14 ...	51	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 17 ...	62	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 21 ...	70	—	—	81	21	—	—	—	—	—	—	—	—	—	—
,, 24 ...	62	78	—	76	22	—	—	—	—	—	—	—	—	—	—
,, 29 ...	58	63	10	79	50	—	—	—	—	—	—	—	—	—	—
Sept. 7 ...	75	72	40	83	33	—	—	—	—	—	—	—	—	—	—
,, 12 ...	75	79	67	79	24	—	—	—	—	—	—	—	—	—	33
,, 17 ...	—	87	82	—	28	29	—	—	—	—	17	—	—	—	43
,, 20 ...	—	82	65	57	52	30	22	—	—	63	25	—	—	16	57
,, 24 ...	—	77	88	—	50	48	23	20	—	39	63	—	—	38	47
,, 28 ...	—	71	68	70	50	71	29	—	—	50	50	—	37	38	47
Oct. 1 ...	66	64	84	50	60	69	55	30	—	50	72	29	0	49	7
,, 4 ...	69	75	37	—	55	60	68	—	62	45	80	27	15	36	15
,, 8 ...	85	46	64	—	50	72	23	—	43	67	85	20	0	53	26
,, 11 ...	72	—	47	60	70	80	62	45	75	28	72	88	38	62	18
,, 15 ...	91	—	75	—	70	70	56	—	33	27	60	33	29	60	30
,, 18 ...	75	—	58	100	75	62	49	53	39	21	70	50	0	10	14
,, 22 ...	86	—	86	—	68	33	45	—	75	30	52	50	22	25	17
,, 25 ...	68	—	62	74	37	26	21	32	27	50	56	50	67	37	37
,, 29 ...	68	—	56	—	40	63	31	—	17	—	47	—	4	30	32
Nov. 5 ...	70	—	60	59	—	17	50	40	29	—	—	—	24	38	33
,, 8 ...	85	—	50	75	—	66	26	—	55	—	—	—	33	63	22
,, 13 ...	66	—	—	71	—	67	59	22	—	—	—	—	38	66	52
,, 15 ...	65	—	—	66	—	83	40	—	—	—	—	—	38	62	24
,, 19 ...	59	—	—	63	—	20	—	—	—	—	—	—	38	35	22
,, 22 ...	67	—	—	—	—	63	—	—	—	—	—	—	40	53	47
,, 26 ...	55	—	—	—	—	—	—	—	—	—	—	—	70	57	28
,, 29 ...	66	—	—	—	—	—	—	—	—	—	—	—	55	57	24
Dec. 4 ...	—	—	—	—	—	—	—	—	—	—	—	—	67	13	21
,, 8 ...	—	—	—	—	—	—	—	—	—	—	—	—	76	43	15
,, 11 ...	—	—	—	—	—	—	—	—	—	—	—	—	47	45	—
,, 15 ...	—	—	—	—	—	—	—	—	—	—	—	—	20	36	—
,, 18 ...	—	—	—	—	—	—	—	—	—	—	—	—	34	35	—
,, 20 ...	—	—	—	—	—	—	—	—	—	—	—	—	50	66	—
,, 24 ...	—	—	—	—	—	—	—	—	—	—	—	—	30	5	—
,, 29 ...	—	—	—	—	—	—	—	—	—	—	—	—	70	13	—
Jan. 3 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	50	—
,, 7 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—
,, 10 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—

Continuously high parasitism is a feature of the records from tomato crops. Data in this respect are given in Table II, which also contains the serial estimates for marrows, cucumbers and wild food-plants.

As large egg populations are involved as regards tomato field crops, it is clear that the percentages of parasitism during the sustained high levels, indicated in figs. 1 and 3, are attributable largely to the dominant influence of the records from this crop.

Reference has been made to the fact that the curves of flowering and of oviposition by the moth are related very closely. On account of these relationships, the duration of parasite activity with regard to *Heliothis* eggs on any one kind of crop, especially opportunities for the intervention of a multiplying progeny of a parasite, depends to a large extent on the flowering habit of the plant. Peas and beans flower for 30 to 40 days, cucumbers and marrows for 50 to 60 days, and tomatoes for 65 to 70 days ; there is thus considerable difference in the periods of associated oviposition and in opportunities for sustained parasite activity. The mean developmental period of *Telenomus* is 14 days and the longevity of the adult female about 18 days, so it is evident that the prolonged presence of abundant host material on the tomato, cucumber and marrow crops would favour additive parasitism and lead to the situation indicated in Table II. As the egg population rises coincidently with increased flower production, reaching a peak about midway in the flowering life of the plants, the continued high levels of the parasitism are, therefore, indicative of increases in the parasite populations.

TABLE III.

Parasitism of Heliothis *Eggs on the principal Wild Food-Plants.*

Food-plant.	Modal percentages of eggs parasitized by		Total per cent.
	Trichogramma	*Telenomus*	
Datura stramonium, L.	29	19	48
Nicandra physaloides, Gaertn.	8	9	17
Malvastrum tricuspidatum, A. Gray ...	24	13	37
Sonchus oleraceus, L.	16	14	30
Xanthium pungens, Willd.	11	12	23
Sida spp.	18	15	33
Physalis angulata, L.*	32	22	54
Chenopodium murale, L.	12	13	25

* The eggs of *Heliothis assulta* on this plant are also parasitized by both parasites.

Occasionally both parasites have been recorded from eggs collected from 14 other wild food-plants of *H. armigera*. A list of these is given in Part I.

Tobacco, maize and wild food-plants comprise the breeding grounds of the bollworm from mid-November to late January.

Bollworm eggs are laid almost exclusively on the flower-heads of tobacco plants and, as these are plucked continuously to encourage leaf-growth, most of the eggs are removed with the flowers and little information has been gained with regard to parasite association.

At this time of year only small patches of maize are grown for vegetable purposes and, although sometimes the eggs on maize are parasitized heavily by both parasites, a very inconsiderable fraction of the egg population, as a whole, is involved.

Importance attaches mainly to conditions in the colonies of wild hosts. For the greater part these are scattered widely and have not been surveyed equivalently. The records quoted are mainly from mixed colonies of weeds that develop in and surrounding cropped lands. It is from the eggs on these wild food-plants that *Trichogramma* first appears in numbers and soon gains ascendancy over *Telenomus.* Apart from the ruling high temperatures and higher humidity, which appear to be inimical to *Telenomus,* the developmental period of *Trichogramma* is only 7 days and, commonly, two to four or more *Trichogramma* emerge per egg as against one *Telenomus* ; consequently a decline in the numbers of *Telenomus* would be expected. From his work on *Heliothis* in Rhodesia, Jones (*l.c.*), has contributed the results of extensive studies on the biology and interrelationships of these two parasites. He concludes that *Trichogramma* is definitely the superior species when they are active in the field at the same time.

The wild food-plants are present in all stages of growth, and flowering does not occur in quantity over continuous areas of any one species of plant. In consequence, the egg-laying moths are not attracted to any particular quarter and a highly discreet distribution of eggs is found. Although abundant host material is present over a period of about two months, it is much scattered and the areas to be traversed by parasites before encountering eggs are much greater than is the case in planted crops. This may be advanced in explanation of the relatively low parasitism under seemingly favourable conditions.

Eighty to 90 per cent. of the rain-grown crops consist of cotton and maize where, as seen from Table I, parasitism on the whole is of a low order, particularly in eggs from cotton. Not infrequently a high parasitism has been found in the eggs from individual crops, but cases of this nature will be considered in a later paper on studies of bollworm populations in cotton and maize. Reference may be made again to the earlier work of Parsons & Ullyett[1], where the status of naturally-bred *Trichogramma* in the summer season is touched upon.

Influence of Egg Parasites on the Limitation of Bollworm Populations.

Records of egg parasitism have been taken in conjunction with enquiries of long standing on the extent of larval mortality in the various types of crop. These enquiries have been made partly with the aim of assessing the potential issue of bollworm moths from the constituents of the winter and subsequent breeding areas, and of helping to state the chain of events leading to the appearance of moths in cotton.

Although *Telenomus* is obviously a potent agent in limiting the size of the *initial* larval populations in some winter-breeding crops, it does not necessarily follow that proportionately fewer moths will emerge from those lands, because the factors operating to destroy larvae are not common to all the food-plants of the bollworm. The numbers of larvae which mature may bear little or no relation to the size of the initial population. In support of this statement some results of studies on larval survival on those crops wherein *Telenomus* exhibits activity are given in Table IV.

The data of Table IV are based on hatched eggs (or initial larval population). It is seen that there was no survival on cucumbers and the same holds for many of the tomato crops studied. Marrows, the other crop on which eggs are fairly heavily parasitized, exhibits the greatest larval survival. The data from peas contain instances of very low survival despite the dearth of egg parasitism. Though more eggs were parasitized on beans, the survival there was of much the same order as for peas. It may be assumed for these instances that the influence, if any,

TABLE IV.

Proportions of Mature Larvae found from varying Egg and Larval Populations at different Levels of Egg Parasitism by Telenomus ullyetti.

Crop	Range of egg numbers per sq. yard.	Range of parasitism per cent.	Range of mature larvae as percentage of *hatched* eggs
Tomato	24–100	60–73	0–4·5 (frequently nil)
Cucumber	17–80	43–63	nil—all cases
Marrow	44–106	31–51	6·2–6·6
Pea	20–89	3–20	1·4–5·8
Bean	7–45	11–34	·5–5·1

of egg parasitism on the ultimate dimensions of the larval population is obscured by other factors.

Discussion on egg parasites may be closed with a note on the relative extent of the individual crops in the winter-breeding category. The acreages planted to the several crops vary somewhat every year, but the proportions given below are representative for the area where the survey has been most intensive, viz. :—

Pea	40 per cent.
Bean	14 ,, ,,
Tomato	22 ,, ,,
Marrow	11 ,, ,,
Cucumber	6 ,, ,,
Sundry crops	7 ,, ,,

According to the data on larval survival, and regardless of the status of egg parasitism, the crops with the highest potentials for moth production are marrow, pea and bean, in order of importance per unit-area. On the acreage basis, however, peas are the principal winter breeding-grounds. With a greater egg population and greater larval survival, marrows outweigh beans in this respect. Cucumbers are of no importance and tomatoes infrequently of importance in the subsequent incidence of moths.

Incidence of Larval Parasites.

The incidence of larval parasites has been determined from observations on larvae collected weekly or twice-weekly in all crops and weed colonies included in the general survey.

On each occasion the larvae were taken from independent, but representative, plant samples of the order and distribution utilized in the determination of bollworm incidence and egg parasitism.

First and second instar larvae are difficult to detect. The difficulties vary with the habit of the food-plant, and the proportions collected of these stadia are never fully representative. Despite precautions, deaths following symptoms resembling polyhedral disease may be more prevalent in the insectary than in the field; consequently more and earlier deaths in the collected material may ensue, thus obscuring the levels of parasitism in specific instances. But over long periods the samples have been sufficiently free from this complication to supply an index of the degrees of larval parasitism. The methods provided for the recognition of the parasites present and the stadia attacked, and supplied data on season and crop associations.

Records for the past five years on some 16,000 larvae are reviewed in the following. As in the case of egg parasitism, the information and conclusions are based on data accumulated in the Barberton area. Similar work in Natal and Swaziland was abandoned upon learning that the principal parasites are common to all the areas surveyed.

Parasites of Heliothis *Larvae recorded at Barberton.*

DIPTERA.

TACHINIDAE.

Sturmia inconspicua, Mg.
Tachinomima longirostris, Mg. var. *salmacina*, Speis.
Pales pavida, Mg. var. *caerulea*, Jann.
Pales nigronitens, Villen.
Gonia bimaculata, Wd.
Nemoraea capensis, R. D.
Pseudogonia cinerascens, Rond.

HYMENOPTERA.

ICHNEUMONIDAE.

Metopius discolor, Tosq.
Pristomerus sp.
Charops spp. (2)
Angitia sp.
Genus ? (Pristomerini)

BRACONIDAE

Chelonella curvimaculata, Cam.
Cardiochiles nigricollis, Cam. (=*tegularis*, Brues)
Apanteles maculitarsis, Cam.
Apanteles sp., near *aethiopicus*, Wilkn.
Microbracon brevicornis, Wesm.

EULOPHIDAE

Euplectrus sp.

Thirteen of the parasites in the list have been recorded comparatively rarely and the total parasitism attributable to them is less than 5 per cent. of the parasitism as a whole. The following notes have been recorded on their periods and sites of occurrence, the stadia attacked, and other matters of interest.

Pales pavida.—Occurs in 2nd to 6th stadia, and in the pupa; from August to October and January to April, on peas, citrus, cotton, maize, and groundnuts Uncommon since 1934—year of heavy bollworm attack on citrus and vegetable crops. Emerges most frequently from the bollworm pupa. Developmental period ranges from 29 to 44 days.

Pales nigronitens.—Confused in the records with *Pales pavida*.

Gonia bimaculata.—Attacks 5th stadium, in January, on cotton.

Nemoraea capensis.—Occurs in 5th and 6th stadia, in September and October, on peas and citrus ; rare.

Pseudogonia cinerascens.—Occurs in 4th, 5th and 6th stadia, and in the pupa, from October to January, on ratoon cotton, peas, and citrus. Rare since 1934. Most frequent in pea-bred larvae. Commonly emerges from bollworm pupa after total development periods of 30 to 37 days.

Metopius discolor.—Occurs in 5th and 6th stadia, and in the pupa, from October to February, on maize, cotton, beans and tomato. Emerges from the pupa. Development period is 32 to 39 days.

Pristomerus sp.—Occurs in 1st to 5th stadia, from November to March, on maize, cotton and groundnuts. Rare since 1934. Parasitizes 2nd and 3rd stadia mainly. Larval period 7 to 9 days, pupal period 9 to 11 days.

Charops spp.—Occurs in 3rd and 4th stadia, in May and December, on tomato and ratoon cotton. Observed on six occasions only, 1934–35. Bred from *Phytometra orichalcea* on peas in 1936.

Angitia sp.—Attacks 3rd stadium, in September and October, on peas and maize. Found only in 1936 and 1937. Larval period 7 to 11 days, pupal period 12 to 15 days.

Microbracon brevicornis.—Occurs in 5th and 6th stadia, from September to November, on maize, tobacco, marigold and *Antirrhinum.* Very common, except from larvae on *Antirrhinum majus.*

Euplectrus sp.—Occurs in 1st, 2nd and 3rd stadia, from August to November, on peas. Larval period 6 to 9 days, pupal period 9 to 13 days (up to 20 days); 1 to 7 *Euplectrus* emerge from a larva.

Another member of the PRISTOMERINI, but of undetermined genus, was taken on a few occasions from larvae feeding in November and December 1934 on ratooned cotton. According to communications from the Imperial Institute of Entomology, this and the other undetermined Hymenoptera are probably new species belonging to little-known groups.

Seven (including two species of *Charops*) of the minor parasites occurred in notable numbers from *Heliothis* larvae only during the " Bollworm Year " of 1934–35, when the larval populations were unusually large. *Angitia* appeared only in 1936–37.

Euplectrus has been taken in some numbers from *Phytometra* and *Laphygma* larvae present with *Heliothis* and a casual relationship is suggested.

Taylor[7] has reported that, apart from two instances of larvae collected by Ullyett from marigold, *Microbracon brevicornis* had been found to attack *Heliothis* only when feeding on *Antirrhinum majus*, and he quotes a statement by Picard & Rabaud that in certain cases the parasite is not attracted by specific insects as much as by plants on which these live. Our extended observations confirm Taylor's assertion of the *Antirrhinum* relationship, but very occasionally the larvae on tobacco and maize are attacked also. It may be added that Taylor (*l. c.*) and Parsons & Ullyett[2] bred and released *Microbracon* experimentally in commercial crops for purposes of bollworm control during the summer season. It was found that larvae were parasitized, but under the summer (January and February) combinations of temperature and humidity, rapid decomposition of the parasitized larvae ensued before the parasites could develop fully. The larvae of the maize stalk-borer, *Busseola fusca*, Fuller, which are parasitized by *M. brevicornis* under natural conditions, decompose similarly during the summer season, whereas in the earlier, drier conditions of the year, parasitized stalk-borers in maize, and *Heliothis* on *Antirrhinum*, commonly remain unputrified.

Gonia bimaculata is an occasional parasite of the bollworm of the first summer generation on cotton. Another and frequent host of *Gonia* is the cutworm, *Euxoa segetum*, Schiff. The destruction of cutworm food, and persistence of food scarcity entailed in the preparation of cotton lands and later cultivations of the crop, reduce the numbers of cutworms very materially and possibly the occasional parasitism of *Heliothis* is a reflection of this situation.

Metopius discolor has appeared every year since 1930 and is the most important of the minor parasites. Most frequently it emerges from the bollworm pupa. It is relatively large and is unlikely to escape through the meshes of the pupal cages in use, but it may be overlooked oftener than are Tachinids and its frequency may have been underestimated. It destroys mature larvae and pupae from early maize, which otherwise would contribute to the moths responsible for the first and principal infestation of rain-grown cotton. If more abundant, *Metopius* would be an important factor in the limitation of moth numbers, but seasonal increases have not been recorded.

Some particulars of stadia, season and crop associations of the more important parasites are summarized below.

Sturmia inconspicua.—Occurs in 2nd to 6th stadia, and in the pupa, from September to May, on all field and orchard crops and wild food-plants ; recorded on 723 occasions. Parasitism of the 5th and 6th stadia predominates. The host feeds normally until 2–3 days before the parasite larva emerges. Usually one fly emerges per host, but 2 are frequent, occasionally 3, and as many as 8 have been recorded. *Sturmia* is particularly abundant in maize and cotton-bred larvae. According to Dr. Villeneuve, of Paris, specimens sent included the varietal form, *imberbis*, which has not been separated in these records. Larval period 10 to 14 days, pupal period 8 to 17 days, usually 12 to 15 days. Emergence from over-wintering pupae may be 60 to 120 days from pupa.

Tachinomima longirostris var. *salmacina.*—Occurs in 3rd to 6th stadia, and in the pupa, in all months of the year, on citrus, most winter and all summer crops and wild food-plants ; recorded on 550 occasions. Parasitism is confined largely to the 5th and 6th stadia and emergence from the bollworm pupa is very frequent. Superparasitism is rare. It is most abundant in the summer season, and is then of equal importance with *Sturmia* as a parasite of larvae on maize and cotton. Appears sparsely in the winter, associated mainly with larvae on tomato. Larval period 10 to 12 days, pupal period 14 to 19 days.

Apanteles maculitarsis.—Occurs in 1st, 2nd and 3rd stadia, at irregular times, on all cultivated crops ; recorded on 297 occasions. Exhibits partiality for 1st instar larvae. Most frequently recorded from larvae on peas during August to October. Larval period 8 to 10 (up to 17) days, pupal period 4 to 10, usually 7 to 8 days.

Apanteles sp., near *aethiopicus*. Occurs in 1st, 2nd and 3rd stadia, from August to November, on peas ; recorded on 78 occasions. Of irregular appearance, but frequent in larvae from peas, especially of the first stadium. Larval period 7 to 10 days, pupal period 6 to 8 days.

Chelonella curvimaculata.—Occurs in 2nd, 3rd and 4th stadia, from August to September and December to March on peas (only from *Phytometra orichalcea*), maize, cotton and wild food-plants ; recorded on 133 occasions. Frequent in early maize-bred larvae in December and January ; also from larvae bred on wild plants, especially *Datura stramonium*. Larval period 8 to 10 days, pupal period 9 to 12 days.

Cardiochiles nigricollis.—Occurs in 1st to 5th stadia, from December to April, on cotton, maize and groundnuts ; recorded on 322 occasions. Parasitizes 2nd and 3rd stadia mainly. Incident for greater part in cotton-bred larvae. Larval period 10 to 13 days, pupal period 12 to 16 days ; overwinters in the cocoon.

The subject of larval parasitism has been considered from two main points of view.

Firstly, it was desired to ascertain the rôle of parasites in reducing the scale of damage from bollworm infestations. As the ultimate aim of this work is to find measures for the alleviation of bollworm damage to cotton, particular interest has attached to the incidence of larval parasitism during attacks on cotton and on other crops associated seasonally with cotton. It was also, however, convenient of arrangement and of value in population studies to gauge larval parasitism throughout the whole chain of bollworm breeding, and attempts to that end have been made.

Secondly, information was sought on the extent to which parasites destroy mature larvae and pupae. With this information and that derived from other studies on larval and pupal mortality, it was hoped to characterize the propensity for moth production of the various breeding grounds. These enquiries were concerned particularly with moth production from (1) the breeding grounds existing immediately prior to the cotton-growing season, and (2) from areas of maize and other crops that are grown beside cotton, or in its neighbourhood, and which, though more attractive to the moth for oviposition than cotton, might, through higher larval survival and shorter periods of bollworm association, soon enhance the moth population to the later detriment of cotton. The portion of the larval population that attains maturity is very small (Table IV), and cases of parasitism in the late instars that may exert little influence in estimates based on all stadia may well represent a high parasitism of the mature larvae.

The information gained as to the levels of larval parasitism is presented in accordance with the points of view outlined.

TABLE V.

Frequency Distributions of the Total Parasitism of the Larval Population on each Sampling Occasion.

Range of parasitism per cent.	Frequencies of occurrence				
	1934–35	1935–36	1936–37	1937–38	1938–39
0–2·5	8	18	19	15	10
2·5–5·0	6	8	11	7	7
5·0–7·5	3	7	11	4	7
7·5–10·0	13	10	13	7	15
10·0–12·5	5	6	3	5	6
Sub-total of occasions ...	(35)	(49)	(57)	(38)	(45)
12·5–15·0	7	5	2	5	4
15·0–17·5	7	3	2	2	2
17·5–20·0	6	2	3	7	4
20·0–22·5	3	3	1	3	1
22·5–25·0	4	1	1	3	0
Sub-total of occasions ...	(62)	(63)	(66)	(58)	(56)
25·0–27·5	3	1	3	1	2
27·5–30·0	1	0	0	2	0
30·0–32·5	1	1	1	1	0
32·5–35·0	2	1	1	0	1
35·0–40·0	1	0	0	1	0
Totals ...	70	66	71	63	59

Levels of Total Parasitism of Larvae in relation to Attacks in Progress.

The estimates of the levels of combined parasitism over *all* larvae collected on each weekly or bi-weekly occasion do not exhibit seasonal trends, if we may except the months of May, June and July, when *Heliothis* is comparatively inactive. Viewing the situation as a whole, great variability is found between the levels of parasitism per record. This is due in a large measure to the varying contributions of larvae from the different varieties of food-plant, to unequal proportions of the stadia present, and to the varying incidence of " disease " in the collections taken serially. Although each estimate of parasitism may be valid for the occasion, and representative conditions do come under observation over a run of occasions at short intervals of time, the data on total parasitism of total larvae are scarcely informative when viewed chronologically. It is more useful, therefore, to indicate the levels of total parasitism by means of frequency distributions (see Table V).

Cases when very few larvae were collected and when " disease " was very pronounced have been omitted.

It is evident from the records for five years in Table V that the larval population as a whole was rarely parasitized beyond 25 per cent. ; commonly it was less than 10 per cent. and very frequently less than 5 per cent. These ranges of parasitism apply equally to bollworm on the various combinations of food-plants present during the winter, intermediate and summer seasons. Regarded in a district-wide application, they evince the rather minor rôle of parasites in limiting the scale of bollworm attacks.

As the parasite community in some crops differs, the degrees of parasitism of larvae feeding on the several kinds of food-plant have been computed separately ; these are summarized in Table VI.

TABLE VI.

Parasitism of Larvae on different Food-Plants.

Crop period	Food-plant	1934–35		1935–36		1936–37		1937–38		1938–39	
		A	B	A	B	A	B	A	B	A	B
Winter season	Cucumber ...	0·0	0·0	7·7	0·0	1·7	0·0	0·0	0·0	0·0	0·0
	Tomato ...	2·5	0·0	7·3	0·0	8·8	8·2	2·8	0·0	10·5	14·5
	Pea	3·9	12·5	4·4	4·0	10·5	16·0	2·5	3·3	19·0	12·0
	Bean	12·0	29·5	8·6	25·0	14·7	53·0	6·5	36·0	4·4	38·0
	Marrow ...	1·6	0·0	9·5	12·0	1·7	0·0	1·6	4·7	3·4	0·0
Intermediate season	Wild food-plants	5·4	16·6	7·4	19·0	2·0	11·0	4·0	8·4	3·0	6·5
	Maize	6·0	22·0	9·1	31·0	10·0	14·0	14·5	16·0	19·0	37·0
	Tobacco ...	—	—	—	—	7·5	9·0	0·0	0·0	0·0	0·0
Summer season	Maize	10·9	22·1	6·7	16·0	9·8	23·0	13·0	21·0	10·0	13·0
	Cotton	16·5	9·0	6·0	3·6	23·3	30·0	29·0	13·0	17·0	10·0

The A columns in the Table give the mean percentages of parasitism found from the larvae collected in numerous examples of each of the important crops and weed colonies each year. The figures are the means of the parasitism recorded for individual crops or wild food-plant situations and thus the variations in larval numbers have entered into the calculations ; owing to the presence in most cases of one or more instances of higher parasitism, this treatment results in indicating a generally higher range of parasitism than the distribution (for all recording occasions) in Table V conveys. The standard errors of several of the means, both within and between cases, are too high to admit of statistical analysis of the data in the A columns as a whole. Lower parasitism is associated, however, with the larvae from cucumber, tomato and marrow crops. Cotton-bred larvae were most heavily parasitized, except in 1935–36, a late season of very light bollworm attack. The parasitism of cotton-bred larvae was due very largely to the Braconid, *Cardiochiles nigricollis*, which mainly attacks the 2nd and 3rd instars. The destruction of these young larvae contributes in an important degree to a characteristic, sharp fall in larval numbers on cotton, particularly of the second summer generation.

Full appreciation of the part played by parasites during the bollworm infestation of a crop cannot be gained without knowledge of other factors affecting larval mortality. Studies at Barberton of the fate of larval populations on the various types of food-plant, and of some of the factors involved, allow of more accurate assessment of the rôle of parasites ; but detailed instances will best be quoted later in their relation to the results of this other work.

Parasitism of mature Larvae and Pupae.

The estimated proportions of mature larvae and pupae destroyed by parasites are given in the B columns of Table VI.

Of the winter season crops, it has been stated (p. 99) that *Heliothis* larvae do not mature on the cucumber plant and the same holds true for many of the tomato crops studied. In both cases it is fairly evident from feeding tests that nutritional factors are involved. Occasionally the tomato-bred larvae and pupae were lightly parasitized. Little or no parasitism of this description has been found for marrows, on which, as indicated in Table IV, the survival of larvae to maturity is proportionately and numerically high. The rate of parasitism for peas is also of a low order. The bean-bred material, on the other hand, suffers a notably heavy destruction ; these records are mostly from pupal emergences of *Sturmia* and *Tachinomima*.

The information on parasitic destruction of pupae allows of more penetrating estimates of the breeding propensity of a crop, as the estimates are based primarily on the proportions of the larvae that attain maturity.

The first infestation of cotton is due to moths emerging between the winter and summer seasons from wild food-plants, maize and tobacco. Larval survival to maturity was found from tobacco only in a few instances where wholesale de-flowering had been neglected. A relatively high proportion of the mature larvae and pupae produced in the small patches of early-planted maize are destroyed, but diminution in the predominant breeding areas of wild food-plants is decidedly less extensive, and these are further confirmed in their importance as the principal source of the moths which enter cotton to occasion the first infestation of the season.

Maize is particularly attractive to the egg-laying moth and is grown in the neighbourhood of cotton as a protective measure. On account of its short-flowering habit, maize is only briefly attractive and moths emanating from it seek other crops. They emerge in time to lay on flowering cotton and should particularly large numbers of moths be bred from maize, its use as a bollworm trap-crop should be discouraged. The extent of larval survival and parasitism of mature larvae and pupae as regards maize are, therefore, of special interest.

As compared with cotton, maize-laid eggs are more heavily parasitized, but the initial larval population is frequently very large. It is seen from the A columns of Table VI that the immature stages of maize-bred larvae are only lightly parasitized, but it is known from studies of larval survival in large populations on both cotton and maize that proportionately fewer of the maize larvae reach maturity. This is due mainly to the fact that the older larvae on maize feed at one point on the plant, the cob, where cannibalism supervenes and predators are most effectively active. Contrasted with this, the larvae and their food are widely dispersed on the cotton plant, more so than on any other of the cultivated plants.

Turning to the B columns of the Table, it is evident that in four of the five years parasites destroyed a considerably higher proportion of the mature larvae and pupae from maize than from cotton. Actually most of the older larvae feed near the tip of the maize cob, and because of their exposure, parasitism greater than found would be expected. On these grounds and for other reasons, of which mention must be deferred, maize is regarded as having the lower propensity for moth production.

Summary.

Egg Parasites.—In the Eastern Transvaal, Swaziland and Natal the eggs of *Heliothis armigera* are parasitized by *Trichogramma luteum*, Gir., and *Telenomus* (*Phanurus*) *ullyetti*, Nixon. No other egg parasites have been encountered.

Representative samples of eggs were collected weekly or twice-weekly over a period of seven years and over wide areas from the various cultivated crops and colonies of wild food-plants which exemplify the annual chain of breeding sites of *H. armigera*. The collected eggs were incubated to determine the " active " fraction derived after withdrawal of the infertile portion and of eggs exposed for less than 24 hours to parasite action. Observed parasitism was computed against the " active " eggs and is regarded as an index of the parasitism in the field. Running indices of this nature are given graphically to indicate the annual incidence of egg parasitism in percentages, which may be viewed in relation to the incidence of bollworm as evinced by oviposition data in the figures given. Sustained high levels of parasitism are associated mainly with the more abundant egg populations on winter-irrigated vegetable crops grown between July and November.

It has been found that *Telenomus* occurs mainly in the period August to December, and *Trichogramma* in the period December to March–April. The high parasitism of the winter egg populations is due, therefore, almost solely to *Telenomus*.

Evidence is submitted that the levels of parasitism in certain crops are commonly much higher than in others. Explanations are suggested by consideration of sites of egg deposition, accessibility of eggs, plant habit, vegetative and flowering, and, particularly, the known oviposition-flowering relationship of *Heliothis* moths. The latter has an important bearing on the persistence of host material and governs opportunity for the intervention of parasite progeny in increasing numbers.

Records on the status of egg parasitism have been taken in conjunction with investigations of the extent of larval mortality associated with the various types of crop. The rôle of egg parasites as agents reducing the issue of moths from winter and spring breeding areas is discussed briefly. Comparisons are given to show that the influence wielded is inappreciable even in some cases where parasitism is particularly high.

Larval Parasites.—The identity and incidence of parasites of *Heliothis* larvae in the Eastern Transvaal, Natal and Swaziland, were determined from observations on samples of larvae collected weekly or bi-weekly from the wild and cultivated food-plants that supply the annual chain of breeding sites of *Heliothis armigera* ; records for five years, 1934–1939, are discussed. The samples of larvae were representative except as regards the proportions of first and second instars, which are detected with varying difficulties. Mortality following upon symptoms resembling those of polyhedral disease was a complicating factor, but disease-free periods were frequent enough and of sufficient length to permit the identification of the parasites present, the stadia attacked, and to supply information on season and food-plant associations. Estimates of the degrees of parasitism were obtained.

Nineteen parasites are listed. Thirteen of these were of infrequent occurrence and only 5 per cent. of the total parasitism was attributable to them ; some particulars of these minor parasites are given. Information on the major parasites is recorded more extensively, and references to their individual participation are made.

The subject of larval parasitism is presented from two main points of view, viz. : (1) the rôle of parasites in reducing the scale of bollworm attacks, (2) the part played by parasites in destroying mature larvae and pupae and thus lessening moth production. Evidence on (1) is submitted, firstly, for parasitism over the whole of the bollworm population. It is shown that parasitism rarely exceeded 25 per cent., commonly it was less than 10 per cent., and frequently less than 5 per cent. The levels of parasitism do not exhibit seasonal trends. Secondly, data are given for the mean parasitism of the larval populations on each of the main varieties of crop and for wild food-plant breeding areas ; lower parasitism is associated with the larvae from cucumber, tomato and marrow crops. Cotton-bred larvae were most heavily parasitized. Little differences were found for the remainder.

It is recognized that the part played by parasites cannot be appreciated fully unless viewed in conjunction with other factors affecting larval mortality, to be discussed in a future paper.

Evidence on (2) is submitted for the winter, intermediate and summer breeding grounds. There is no larval survival on cucumbers nor, in most cases, on tomatoes, and parasitism rarely applies. Little or no parasitism was found in mature larvae and pupae derived from the marrow crop. As in this case the survival to maturity is particularly high, an outstandingly large moth production is indicated ; similarly for peas, over a larger acreage. In the winter series of crops, only mature larvae from beans were heavily parasitized, parasites emerging mainly from the pupae.

There was a notable reduction of larvae and pupae produced in early maize but little diminution in this regard was found for the predominant wild food-plant breeding grounds, from which the moths concerned in the first bollworm infestations of cotton are mainly derived.

Summer-grown maize has a relatively lower propensity for moth production than cotton.

Acknowledgments.

Mr. Joseph Marshall has collaborated very extensively in investigations on larval survival from which the parasite data for 1937 to 1939 have been drawn.

Mr. H. Hutchinson and Mr. P. A. Bowmaker, and their staffs, stationed in Swaziland and Natal respectively, collected and examined egg and larval material until it had been determined that the principal parasites are common to the several areas.

Of recent years, the supervision of collections and the keeping of records at Barberton have been performed by Mr. C. E. Booth and it is desired to record appreciation for his exceptional helpfulness.

Grateful acknowledgment is made to the Director and members of staff of the Imperial Institute of Entomology for many identifications.

Mr. A. Cuthbertson, of the Division of Entomology, Southern Rhodesia, very kindly obtained for us opinions on the identity of the Tachinid parasites from Dr. Villeneuve of Rambouillet, Paris.

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THE GALL MIDGES ATTACKING THE SEED-HEADS OF COCKSFOOT, *DACTYLIS GLOMERATA*, L.

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(Plates IV & V.)

Introduction.

The knowledge of gall midges attacking the seed-heads of cocksfoot grass began when H. Loew (1851) described in Germany the female of *Contarinia dactylidis* (H. Lw.). Many years later Miss Metcalfe (1933) re-described *C. dactylidis* and discovered *Dasyneura dactylidis*, Metcalfe, in England. In the meanwhile Bagnall & Harrison (1918) had reported finding gall midge larvae in spikelets of the grass in Durham. Lastly, Jones (1936) had recorded *C. dactylidis* and *D. dactylidis* and reported a third species from Wales. Early in 1938 the present writer received for identification from the Imperial Institute of Entomology specimens of a *Stenodiplosis* reared from cocksfoot seed-heads in New Zealand. In this connexion a new survey of the gall midges attacking the seed-heads of cocksfoot was initiated.

The objects of this paper are threefold, namely : to give an up-to-date account of the knowledge concerning these gall midges, to present the results of this latest survey, and to discuss the species problem with special reference to the *Stenodiplosis* of cocksfoot grass.

Contarinia dactylidis (H. Lw.).

The adult female of this species was described by H. Loew (1851) from specimens reared in Germany. Miss Metcalfe (1933) found it on park grass plots at Rothamsted Experimental Station, Harpenden. Emergence in 1932 began on 3rd June and ended on 24th June, with the maximum occurring on 11th June. The sex ratio of 511 emergences was found to be 34 males to 66 females, which in the present writer's experience is somewhat typical of the genus *Contarinia*. The larvae are fully grown about three weeks after egg-laying but may remain in the heads several weeks longer, unless there is sufficient moisture for them to descend to the soil where they spend the winter. There is only one generation a year. At Rothamsted the infestation in 1931 ranged up to nearly 23 larvae per head, but as several larvae are found together in one floret, probably only four or five ovaries were destroyed. Miss Metcalfe recorded the Scelionid, *Prosactogaster tisias*, Walker, parasitising this midge, the average relative parasitism being at that time 11·6 per cent. Unsuccessful attempts were made to infest *Festuca rubra* var. *arenaria* and *Lolium perenne*. Jones (1936) found that this species was widely distributed in mid-Wales.

The present writer's investigations in 1938–39 showed that *C. dactylidis* also occurs in Co. Antrim, Co. Armagh and Co. Londonderry, in Ireland, and in Shropshire, Leicestershire and Devon, in England.

In 1939 at Harpenden emergence of midges from these localities started on 13th June and ended on 17th July.

Dasyneura dactylidis, Metcalfe.

Miss Metcalfe (*l. c.*) described this species from specimens reared from larvae found on park grass plots at Rothamsted Experimental Station. Emergence in 1932 began on 21st May and ended on 6th June with the crest on 29th May. The sex ratio of 304 emergences was 35 : 65 which is a rather low percentage of males in *Dasyneura*. The larvae are fully grown in about four weeks, but here again the period spent in the grass heads by the fully grown larvae may be prolonged by about four weeks. There is only one generation a year. The larvae feed singly, thus one larva destroys one seed. The maximum infestation at Rothamsted in 1931 was found to be just over three larvae per grass head. The Scelionid, *Prosactogaster tisias*, Walker, was found also parasitising this species, and the relative parasitism varied from 17·5 to 66 per cent. Jones (*l.c.*) found that this midge was widely distributed in mid-Wales but was not very abundant in Cardiganshire. This investigator recorded that on one heavily infested plot at Aberystwyth in 1935 the combined infestation by *C. dactylidis* and *D. dactylidis* showed at least 36 per cent. loss of the seed crop.

The present writer's investigations in 1938–39 showed that *D. dactylidis* occurs also in Devon. Emergence from this sample occurred in 1939 at Harpenden between 26th June and 2nd July.

Sitodiplosis dactylidis, sp. n.

Jones (*l. c.*) reported finding a third species of larva in cocksfoot heads in mid-Wales. This, he writes (*in litt.*, 16.ii.38), is like a *Sitodiplosis*, especially in larval characteristics.

The present writer's investigations in 1938–39 revealed the presence of a *Sitodiplosis* sp. in samples of the grass from Co. Armagh (two localities), Co. Fermanagh, Shropshire and Leicestershire. The samples were kept overwinter in an unheated out-of-door insectary at Rothamsted. Emergence from these samples started at Harpenden in 1939 on 7th June and continued until 17th July. The sex ratio of 567 emergences from one locality in Co. Armagh was 42 : 58. There is presumably only one generation a year. Although parasites were reared from grass samples containing this midge among others, no parasite can at present be definitely stated to attack this species.

This is a typical *Sitodiplosis* and the males may easily be separated from those of the only other species hitherto described in the genus, namely *S. mosellana*, Géhin, on account of differences in the antennal segments. It has been compared with specimens, in the writer's collection, of the latter midge from England, Canada and Japan. The name *S. dactylidis*, sp. n., is proposed for the cocksfoot *Sitodiplosis* and an abbreviated description is given below.

Description.

Male.—Length about 1·5 mm., variable, smaller than *S. mosellana*. Antennae (Plate IV, fig. 1) : length of antennae about equal to that of thorax and abdomen (in *S. mosellana* (Plate IV, fig. 2) the antennae are distinctly longer) ; stems of flagellar segments rapidly becoming successively shorter from the basal segments to the distal one, until on the latter segment there is scarcely any stem ; whereas the necks do not exhibit this successive shortening (in *S. mosellana* there is no such shortening of the stems of the flagellar segments). In all other respects, including colour when alive, closely resembling *S. mosellana*.

Cotypes : Cecid. 4002–4 (Co. Armagh), 4063 (Co. Fermanagh), 4070–3 (Leicestershire) and 4064–6 (Shropshire).

Female.—Length about 2 mm., variable, on an average smaller than *S. mosellana*. In all respects hardly distinguishable from *S. mosellana*, though perhaps slightly paler when alive.

Cotypes : Cecid. 4005–7 (Co. Armagh), 4074–7 (Leicestershire) and 4067–9 (Shropshire).

Stenodiplosis geniculati, Reuter.

(*a*) On *Alopecurus*.—This gall midge is well known as a pest of meadow foxtail grass (*Alopecurus pratensis*) and also *Alopecurus geniculatum*. It was first described by Reuter 1895 from Finland, and also occurs on meadow foxtail throughout England, in the Isle of Man, Wales and Ireland (Barnes, 1930). Recently Gilbert (1935) recorded it on this grass from Canada, and the present writer has been privileged to receive some of these Canadian specimens for his collection. In addition, there are specimens of this species from New Zealand in Dr. E. P. Felt's collection of gall midges in the New York State Museum (first seen by the writer in 1926). They were received from the late Professor M. Bezzi and the slides are labelled "from New Zealand." It is not definitely stated from what grass they were obtained, but in all probability it was meadow foxtail. As, however, Mr. W. Cottier recently (*in litt.*, 1938) wrote that *S. geniculati* had not been recorded from New Zealand, the present writer has endeavoured to find out more concerning the origin of these specimens. Thanks to the courtesy of Dr. R. D. Glasgow, New York State Entomologist, who kindly sent the slides in question on loan, it has been possible to make a re-examination of this material (three slides, no. a2965, bearing 4 females). This confirms that they are *S. geniculati*, Reuter, as they agree in detail with English, Irish and Canadian specimens of this midge. Dr. Parisi, who is in charge of the Bezzi collection, has written (28th August 1938) to say that there are no additional specimens now in Bezzi's collection. Cockayne (1916) when dealing with *Dasyneura alopecuri*, Reuter, in New Zealand stated that this midge was "several brooded," and he figures the pupa as having a dark head and thorax. Both these facts point to the possibility that he may have been dealing unwittingly with both *D. alopecuri* and *S. geniculati*. Taking all the evidence into consideration, one can only conclude that *S. geniculati* was living on meadow foxtail in New Zealand some years ago (about 1916).

In view of the possible doubt concerning the occurrence of *Stenodiplosis geniculati* occurring on meadow foxtail in New Zealand, Mr. W. Cottier had a collection of the seed-heads of this grass made over areas of the South Island and in the Manawatu and Pukekohe districts of the North Island in 1938. Midges were bred out in the laboratory and the specimens were forwarded to the present writer for identification through the Imperial Institute of Entomology. The result of this survey was to show that *S. geniculati* occurs on meadow foxtail at the present time both in the Manawatu (Palmerston North) and Pukekohe districts of the North Island and throughout the South Island (Gore, Dunedin, Balclutha and Invercargill) (Cecid. 4108–4154).

All the specimens received (98 males and 144 females) have been compared with foxtail-reared specimens of *S. geniculati* in the Barnes collection from England, Ireland and Canada.

The bionomics of this species on meadow foxtail have been worked out in some detail (Barnes, 1930). In some localities in England it has two generations a year, the first emerging in April and May and the second from June to August.

(*b*) On *Dactylis*.—Jones (*in litt.*, 16.ii.38) states that he dissected a single larva of a fourth species from a seed of *Dactylis glomerata*. This larva had no anchor process and may possibly be *Stenodiplosis geniculati*.

In the present writer's investigations during 1938–39 of the gall midges attacking *Dactylis* seeds, *S. geniculati* was reared in small numbers between 7th and 17th June from samples of grass received from Co. Armagh (Cecid. 4094), Co. Fermanagh (Cecid. 4098–4107) and Shropshire (Cecid. 4095–7).

(*c*) Experimental transference from *Alopecurus* to *Dactylis*.—It was decided early in 1938 to endeavour to breed on cocksfoot *S. geniculati* obtained from foxtail. Accordingly a sample of meadow foxtail grass known to be infested with this species was collected in Devon. When the summer generation of adult midges emerged, they were transferred to covered plants of cocksfoot obtained previously from the Welsh Plant Breeding Station, Aberystwyth. The plants were grown out in the open at Rothamsted and kept covered with muslin bags. The midges were placed on the cocksfoot in late June and early July. The female midges were observed ovipositing in the flower-heads. In August the seed-heads of the grass were collected and kept over winter in a lamp-glass cage in an unheated insectary. Between 29th May and 7th June, 1939, four female *S. geniculati* midges emerged. These specimens (Cecid. 3998–4001) exhibit the normal characters of *S. geniculati* reared on meadow foxtail.

This is definite evidence that the foxtail *Stenodiplosis geniculati* will under certain conditions oviposit and develop successfully on cocksfoot. It is possible that in certain localities, *e.g.*, Devon, where there is a summer emergence (June to August) of this midge from meadow foxtail, the midges of this flight regularly oviposit on cocksfoot. However, this species has not yet been reared from samples of the latter grass obtained from Devon.

Stenodiplosis geniculati, Reuter, var. **dactylidis,** nov.

Early in 1938 specimens of a *Stenodiplosis* were received through the Imperial Institute of Entomology from Mr. W. Cottier in New Zealand. The midges were from cocksfoot in Wellington and Canterbury, N.Z. They were at first thought to be a new species, for a comparison of them showed them to be intermediate between *S. geniculati*, Reuter, and *S. panici*, Rohd. (1926).* This comparison was made possible owing to Miss H. Dombrowski's kindness in sending specimens (Cecid. 3031–9) of *S. panici* from the U.S.S.R. for the Barnes collection.

Later two further consignments of the midge were received from New Zealand, one collected by Mr. J. G. Gibbs in Canterbury and Wellington, and the other by Mr. W. Cottier at Mt. Albert, Auckland.

It is now considered advisable to regard the cocksfoot midge of New Zealand as a variety of *S. geniculati*, Reuter, and the name *S. geniculati* var. *dactylidis* is proposed for it. The reasons for this are : (1) The occurrence of *S. geniculati* on cocksfoot in England and Ireland, (2) the proved possibility of this species changing its host-plant from foxtail to cocksfoot, and (3) the morphological differences exhibited between *S. geniculati* and this *Stenodiplosis* from New Zealand on cocksfoot. The females of *S. geniculati* (Plate IV, fig. 4) and its variety (Plate IV, fig. 3) can be readily separated by the fact that in the former the basal portion of the 1st flagellar segment of the antennae is about equal in length to that of the 2nd, while in the latter it is distinctly longer than that of the second. In the males the stem of the 3rd flagellar segment is longer than wide in *S. geniculati* and in *S. geniculati* var. *dactylidis* the width of the stem is equal to its length or slightly wider than long.

The differences between *S. geniculati*, *S. panici* and this new variety are small. The least difficult means of separating both sexes are by the proportions of the stems

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* This last named species is usually referred to as *S. panici*, Rohd. Actually there is a rather general description of it printed, with illustrations, in Plotnikov's book and a footnote there (p. 236) stating " this species, not yet described, has been recognised by B. B. Rohdendorf as a new one and will be described by him under this name in the near future." I am indebted to Dr. B. P. Uvarov for this information, the loan of Plotnikov's book and Mr. Rohdendorf's address. The latter wrote (*in litt.*, 17.vi. 39) that he has not yet described the species but merely wrote the rough description for Plotnikov's book.

There is in the Felt collection of CECIDOMYIIDAE in the New York State Museum a slide (a3050) of a *Stenodiplosis* reared from *Panicum* at Los Baños, Luzon, Philippine Islands, and a duplicate slide (Cecid. 434) of this material is in the Barnes collection. Dr. Felt originally identified this material as *S. geniculati*, Reuter. A re-examination shows that these midges are almost certainly *S. panici*, Rohd.

and necks of the male flagellar segments and the proportions of the necks of the female flagellar segments of the antennae.

The stem of the 3rd flagellar segment in the male of *S. geniculati* is about half again as long as broad, while the neck is about twice as long as broad ; in *S. geniculati* var. *dactylidis* the stem is transverse, being as broad as long or slightly broader than long, while the neck is slightly longer than broad ; in *S. panici* the stem is transverse, being half again as broad as long and the neck slightly longer than broad. The stem of the 10th flagellar segment in *S. geniculati* is about twice as long as broad and the neck is about three times as long as broad ; in *S. geniculati* var. *dactylidis* the stem is only slightly longer than broad and the neck is about twice as long as broad.

In the female the necks of the flagellar segments are shortest in *S. panici*, intermediate in *S. geniculati* var. *dactylidis*, and longest in *S. geniculati*. Those of the 3rd flagellar segment in *S. panici* are slightly more than three times as broad as long, those in *S. geniculati* var. *dactylidis* are just over twice as broad as long, and those in *S. geniculati* are about as long as or slightly longer than broad. The necks of the 10th flagellar segment in *S. panici* are at least twice as broad as long, in *S. geniculati* var. *dactylidis* slightly less than twice as broad as long, and those in *S. geniculati* are about as long as broad or longer. In addition, the 12th flagellar segment in *S. panici* has a knob-like prolongation, in *S. geniculati* and its variety the prolongation has no constriction at its base.

There are specimens of this new variety in the Barnes collection from Mt. Albert, Auckland, and Wellington in the North Island and from Canterbury in the South Island (♂♂, Cecid. 3448–51, 4080–1 and 4084–6 ; ♀♀, Cecid, 3452–63, 4078–9, 4082–3 and 4087–9 ; larvae, Cecid. 4090–3).

From information received from Mr. W. Cottier, *S. geniculati* var. *dactylidis* is widespread over the whole of New Zealand, being present on plants growing by the roadside as well as on cultivated seed crops. It is also abundant, the loss of seed being from 20 to 80 per cent., and there is little doubt that this midge causes a substantial reduction in cocksfoot seed production in New Zealand.

Lestodiplosis sp.

Midges of the genus *Lestodiplosis*, whose larvae feed on other midge larvae, have been reared from midge-infested cocksfoot heads. The species involved have not yet been determined. They occur usually only in small numbers, and it can be safely stated that as a rule they do not materially decrease the infestation by the injurious species of gall midges. Midges of this genus have been reared from the following localities in 1939 : Co. Armagh, in Ireland, and in Leicestershire and Shropshire, in England.

Separation of the Species involved.

The adult midges (see Plate V) may be separated with the naked eye on their coloration when alive as follows :—

A. Wings clear.
  B. Lemon yellow-golden abdomen.........*Contarinia dactylidis* (H. Lw.).
  BB. Dull honey-yellow abdomen, dark thorax......*Stenodiplosis geniculati*, Reuter.
  BBB. Carroty red abdomen........................*Sitodiplosis dactylidis*, sp. n.
  BBBB. Dull red abdomen in female, brown abdomen in male......*Dasyneura dactylidis*, Metcalfe.
AA. Wings speckled.
  B. Bright red abdomen......................................*Lestodiplosis* spp.

When dead and faded the species can be distinguished under the microscope as follows :—

A. Wings clear.
B. Claws toothed
C. Ovipositor pocket-shaped......*Dasyneura dactylidis*, Metcalfe.
BB. Claws simple
C. Ovipositor lamelliform..............*Sitodiplosis dactylidis*, sp. n.
CC. Ovipositor needle-shaped.
D. Palpi 4 segments, long...*Contarinia dactylidis* (H. Lw.).
DD. Palpi 3 segments, short.......................................
Stenodiplosis geniculati, Reuter.
AA. Wings speckled.
B. Claws simple, ovipositor lamelliform.................*Lestodiplosis* spp.

The larvae can be separated as follows :—

A. With anchor process.
B. Red .... *Dasyneura dactylidis*, Metcalfe.
BB. Lemon-yellow to gold....................*Contarinia dactylidis* (H. Lw.).
BBB. Orange-carroty red..........................*Sitodiplosis dactylidis*, sp. n.
AA. Without anchor process.
B. Salmon.....................................*Stenodiplosis geniculati*, Reuter.
BB. Blood-red ....*Lestodiplosis* spp.

Besides these colour differences and the presence or absence of an anchor process, the chaetotaxy and morphology of the anal segments are distinct for the separate genera.

It must be understood that the above keys refer only to gall midges found on cooksfoot. For example *Sitodiplosis mosellana* of wheat and *S. dactylidis* are practically the same colour, as are also *Contarinia tritici* of wheat and *C. dactylidis*. In fact, all the above characters are practically of generic value.

Discussion.

It has been shown in the present paper that there are four species and one variety of gall midges, belonging to four distinct genera (*Dasyneura*, *Contarinia*, *Stenodiplosis* and *Sitodiplosis*) which cause a loss of seed in cocksfoot. Any one of the species involved, or a combination of several of them, may at any time become of real importance, although up to the present the only complaint has been with regard to the serious damage caused by *Stenodiplosis geniculati* var. *dactylidis* in New Zealand.

Similarly, on meadow foxtail grass, there are three injurious species, a *Dasyneura*, a *Stenodiplosis* and a *Contarinia*. Other valuable grasses, such as fescue (*Festuca* spp.), Yorkshire fog (*Holcus lanatus*), timothy (*Phleum pratense*), rye grass (*Lolium* spp.), meadow grass (*Poa* spp.), bent (*Agrostis* spp.) and yellow oat grass (*Trisetum flavescens*), have their attendant midges which cause loss of seed. In some cases these midges have been described, in others merely recorded as belonging to a certain genus.

The problem of host-plant specificity is obviously of great importance to seed-growers. The only method of determining this is, of necessity, a programme of several years intensive research work. It would involve maintaining a living museum of the various suspected species of gall midges breeding on their various host-grasses. This in itself requires some skill in rearing midges and growing the grasses. The next step would be experiments to discover whether midges belonging to the same genus but bred on different grasses would crossmate. At the same time frequent attempts would have to be made to induce a species from one grass to breed on another grass. Furthermore, it must be emphasised that negative results must be repeatedly obtained before much reliance should be placed upon them.

Various attempts to carry out investigations on these lines have been made of recent years. For example, in preliminary experiments, one wheat blossom midge *Contarinia tritici*, Kirby, has been reared by the writer up to the larval stage on wheat, rye, couch grass and slender foxtail, and oviposition was once obtained on timothy. On the other hand, it was not possible to induce this species to live on meadow foxtail or perennial rye grass. The above experiments need to be repeated in order to preclude the possibility of contamination.

Miss Metcalfe (*l. c.*) obtained negative results in attempts to breed *C. lolii* on cocksfoot, red fescue and meadow foxtail, and *C. dactylidis* on red fescue and perennial rye grass.

Attempts have also been made unsuccessfully to mate *C. tritici* with *C. merceri*, Barnes, the meadow foxtail *Contarinia.*

Dr. D. P. Jones worked for some time on the same lines, and the results are embodied in his Ph.D. thesis now in the Library of the University of Wales.

The experience of these three workers point to the probability that most of these midges are specific to their own grass genus and will not attempt to attack species in any other genus.

It would appear reasonable to suppose that there is one, or perhaps more, " central " species of *Contarinia* which, by reason of its non-specialisation, can live on several generically distinct grasses in addition to its main host-plant, *e.g.*, *C. tritici* can breed on rye, couch grass and slender foxtail in addition to wheat.

From time to time a number of individuals of such a species may go over to one of these other grasses ; for example, in 1933 following an abnormally warm spring, in which the wheat ears burst their sheaths a fortnight earlier than usual and *C. tritici* emerged about three weeks earlier than in normal years, the numbers of *C. tritici* larvae in 500 ears of wheat was only 1,474 compared with 7,356 the previous year. It is possible that a considerable number of *C. tritici* in 1933 were unable to oviposit on wheat and went over to an alternate host-grass.

Such an abruptly transferred population might become so closely adapted to this alternate host-grass that in the course of years it would become isolated and unable to return to its original host-plant. An isolation factor would, for example, be a close affinity between the development of the flowering of the new host-grass and the ovipositional season of the midge. Later in the evolution morphological differences might appear, and then one would be justified in considering the population to consist of a new species, particularly if no interbreeding could take place.

The belief that this has been the course of the evolution resulting in multiplicity of species in the genera *Contarinia*, *Dasyneura*, *Sitodiplosis* and *Stenodiplosis* is greatly strengthened by the finding of the new variety of *Stenodiplosis geniculati* in New Zealand.

The facts may be summarized as follows. *Stenodiplosis geniculati*, Reuter, occurs on meadow foxtail in Europe, Canada and New Zealand. In Europe it has been known for many years, and it is strongly suspected that it was introduced into New Zealand about twenty years ago. A recent survey has shown that at the present time this species also occurs sparsely on another grass, *i.e.*, cocksfoot, in some localities in England and Ireland. In addition an experiment has shown that this midge obtained from foxtail will breed successfully on cocksfoot. Specimens experimentally reared on cocksfoot, as well as those obtained in the survey from cocksfoot, exhibit the normal characters of *S. geniculati* reared on foxtail. Furthermore, surveys a few years ago did not reveal the presence of *S. geniculati* on cocksfoot in England, and no record of its occurrence has been reported until now on cocksfoot in Ireland, although this grass has been studied there as a seed crop for some years. On the other hand, in New Zealand there is at present a widely spread *Stenodiplosis* midge on cocksfoot. But this midge is morphologically slightly different from *S. geniculati* and is considered to be worthy of classification as a distinct variety.

It is suggested that the midge was introduced some years ago into New Zealand on foxtail and that for some reason or another a certain number of them changed over to cocksfoot. This population flourished on this new host and increased, until now, about twenty years later, it is widespread and has attained the status of a pest. In the course of these years, besides becoming biologically attuned to cocksfoot, this midge has developed distinct varietal characters. On the other hand, in England and Ireland this change over from foxtail to cocksfoot is only now taking place, and there has not yet been sufficient time for the species to have evolved new morphological characters. It may not even be firmly established on cocksfoot. In the course of time this new variety in New Zealand may not be able to return from cocksfoot to foxtail nor interbreed. In that eventuality the variety should be considered a distinct species, and one would have witnessed the evolution of a species.

In view of the fact that the normal *S. geniculati* still occurs in New Zealand on foxtail and that the new variety on cocksfoot has distinct morphological characters, it would be extraordinarily interesting to know whether at the present time this new variety can breed successfully on foxtail, whether such progeny would have the varietal characters or those of *S. geniculati*, and whether interbreeding of the species and its variety can take place. It would also be of great interest to make surveys from time to time of cocksfoot in England in order to discover whether the midge is really establishing itself on this grass, and if so, when new morphological characters develop.

Summary.

An account is given of four gall midges whose larvae damage the seed of cocksfoot, viz. *Contarinia dactylidis* (H. Lw.), *Dasyneura dactylidis*, Metcalfe, *Sitodiplosis dactylidis* which is described from England and Ireland in the present paper, and *Stenodiplosis geniculati*, Reuter. The occurrence of predacious midges of the genus *Lestodiplosis* is also noted.

A short section is devoted to characters by which these midges can be distinguished.

Stenodiplosis geniculati is recorded from one English and two Irish localities on cocksfoot grass for the first time, hitherto it has always been recorded from foxtail. These midges, together with some experimentally bred on cocksfoot from foxtail parents, exhibit the typical characters of this species.

A new variety, *Stenodiplosis geniculati* var. *dactylidis*, is described from cocksfoot in New Zealand.

In a discussion of the host-plant specificity of gall midges attacking grass seeds, it is suggested that the present discovery of *S. geniculati* on cocksfoot in England and Ireland and the occurrence in New Zealand of this new variety exhibiting distinct morphological characters are two steps in the evolution of a new species.

I am indebted to Miss F. M. L. Sheffield for taking the photographs used to illustrate Plate IV. They were taken to show the comparative lengths of the antennal segments and not the chaetotaxy. I am also indebted to Mr. P. S. Milne who took the photographs used to illustrate Plate V.

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EXPLANATION OF PLATE IV.

Fig. 1.—Head and antennae of ♂ *Sitodiplosis dactylidis*, sp. n. (Cecid. 4004), showing reduction of the stems of the flagellar segments (× 46).

Fig. 2.—Head and antennae of ♂ *Sitodiplosis mosellana*, Géhin (Cecid. 2700), showing the long stems of the flagellar segments (× 46).

Fig. 3.—Head and antennae of ♀ *Stenodiplosis geniculati*, Reuter, var. nov. *dactylidis* reared from Cocksfoot in New Zealand (Cecid. 4078), showing that the first flagellar segment is longer than the second (× 46).

Fig. 4.—Head and antennae of ♀ *Stenodiplosis geniculati*, Reuter, reared from Meadow Foxtail in New Zealand (Cecid. 4110), showing that the first and second flagellar segments are equal in length (× 46).

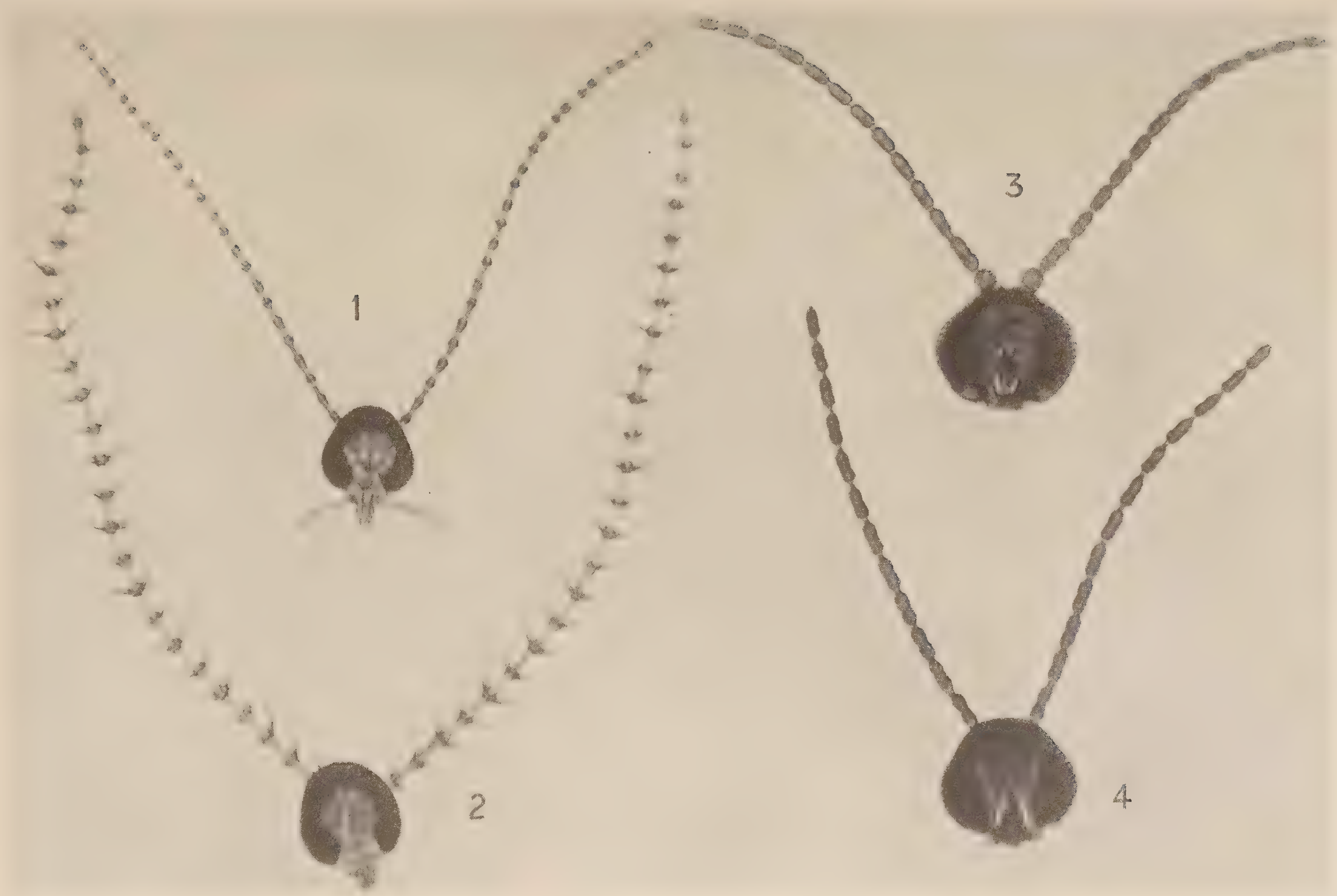
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Fig. 1
Fig. 5
Fig. 9
Fig. 2
Fig. 6
Fig. 10
Fig. 3
Fig. 7
Fig. 11
Fig. 4
Fig. 8
Fig. 12

Figs. 1, 2. *Sitodiplosis mosellana*, Géhin, ♂, ♀.
,, 3, 4. *Sitodiplosis dactylidis*, sp.n. ♂, ♀.
,, 5, 6. *Contarinia tritici*, Kirby, ♂, ♀.
,, 7, 8. *Contarinia dactylidis*, H.Lw., ♂, ♀.
,, 9, 10. *Stenodiplosis geniculati*, Reuter, ♂, ♀.
,, 11, 12. *Lestodiplosis* sp. ♂, ♀. (all × 2·2).

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st October and 31st December, 1939 :—

Mr. A. M. Adamson, Imperial College of Tropical Agriculture :—30 Thysanoptera ; from Trinidad.

Agricultural Research Institute, Wad Medani :—2 species of Coccidae, 10 other Rhynchota, and 1,000 Mites ; from the Sudan.

Dr. F. S. Bodenheimer :—241 Coleoptera, 8 Hymenoptera, 5 Lepidoptera, 99 Rhynchota, and 72 Orthoptera ; from Turkey.

Prof. J. Bayley Butler :—5 Mites ; from Ireland.

Prof. P. A. Buxton, London School of Tropical Medicine :—23 Tabanidae, 3 *Cordylobia* and 2 pupa-cases, and 514 other Diptera ; from various localities.

Mr. E. McC. Callan :—48 *Phlebotomus* ; from Trinidad.

Mr. R. C. Chatterji :—1 Chloropid and 4 Calliphorid larvae ; from Burma.

Mr. W. Cottier, Entomologist :—17 Coleoptera ; from New Zealand.

Chief Plant Protection Officer, Jerusalem :—9 Diptera, 22 Coleoptera, 32 Parasitic Hymenoptera, 17 other Hymenoptera, 2 species of Coccidae, 1 species of Aphidae, 4 other Rhynchota, and 200 Mites ; from Palestine.

Conservator of Forests, British Honduras :—25 Isoptera.

Coryndon Memorial Museum, Nairobi :—54 Diptera, 103 Coleoptera, and 24 Isoptera ; from Kenya Colony.

Mr. A. Cuthbertson, Entomologist :—10 Coleoptera and 2 Blattidae ; from Southern Rhodesia.

Mr. J. L. Froggatt, Government Entomologist :—7 Diptera, 56 Coleoptera, 107 Hymenoptera, 8 Lepidoptera, 2 species of Coccidae, 1 species of Aleurodidae, 12 other Rhynchota, 6 Dermaptera, and 150 Mites ; from New Guinea.

Game Warden, Nairobi :—3 Plecoptera ; from Kenya Colony.

Prof. P. Gerard :—10 Diptera, 4 Coleoptera, and 50 Parasitic Hymenoptera ; from Belgium.

Mr. F. D. Golding, Government Entomologist :—3 Coleoptera and 15 Rhynchota ; from Nigeria.

Government Entomologist, Lyallpur :—70 Coleoptera ; from the Punjab.

Government Entomologist, Njala :—28 *Stomoxys*, 25 other Diptera, 9 Parasitic Hymenoptera, 7 other Hymenoptera, 41 Lepidoptera, and 3 Trichoptera ; from Sierra Leone.

Mr. W. B. Gurney, Government Entomologist :—100 Psyllidae ; from New South Wales.

Mr. H. Hargreaves, Government Entomologist :—158 Diptera, 91 Coleoptera, 7 Parasitic Hymenoptera, 2 other Hymenoptera, 24 Lepidoptera, and 18 Rhynchota ; from Uganda.

Mr. G. V. Hudson :—7 Coleoptera ; from New Zealand.

Dr. J. C. Hutson, Government Entomologist :—4 Coleoptera and 54 Parasitic Hymenoptera ; from Ceylon.

Imperial Entomologist, New Delhi :—4 Lepismidae ; from India.

Imperial Institute, London :—12 *Cassia fistula* pods attacked by Lepidopterous larvae, and 2 Lepidopterous larvae ; from India.

Institute for Medical Research, Kuala Lumpur :—396 Diptera and 222 pupa-cases, and 65 Parasitic Hymenoptera ; from Malaya.

Institute for Plant Diseases, Buitenzorg :—10 Coleoptera and 4 Lepidoptera ; from the Dutch East Indies.

Mr. C. B. R. King, Tea Research Entomologist :—37 Diptera ; from Ceylon.

Mr. O. B. Lean, Imperial Chemical Industries :—300 Mollusca ; from England.

Mr. R. A. Lever, Government Entomologist :—90 Diptera and 6 pupa-cases, 145 Coleoptera and 10 larvae, 208 Parasitic Hymenoptera, 39 Lepidoptera, 10 Thysanoptera, 6 species of Coccidae, 12 Cimicidae, 37 other Rhyncota, and 10 Mites ; from the Fiji Islands : also 2 Diptera, 6 Coleoptera, and 13 Rhynchota ; from the Samoan Islands.

Mr. C. J. Louwerens :—46 Coleoptera ; from Java.

Mr. H. M. Morris, Government Entomologist :—1 species of Coccidae ; from Cyprus.

Dr. K. R. S. Morris, Entomologist :—2 Coleoptera and 16 Parasitic Hymenoptera; from the Gold Coast.

Public Works Department, Tulagi :—5,000 Isoptera ; from the Solomon Islands.

Mr. H. W. Simmonds :—1 Scoliid ; from Zanzibar.

Mr. J. H. Smith, Senior Research Officer :—47 Diptera, 22 Parasitic Hymenoptera and 7 cocoons ; from Queensland.

Mr. A. S. Talhouk :—19 Parasitic Hymenoptera and 32 Cynipidae ; from Syria.

Mr. L. B. Uichanco :—3 Coleoptera and 1,450 Parasitic Hymenoptera ; from the Philippine Islands.

Mr. J. M. Waterston, Plant Pathologist :—226 Coleoptera and 5 Ticks ; from Bermuda.

Mr. E. Whitbread :—40 Parasitic Hymenoptera ; from New South Wales.

Mr. F. Wilson :—7 Diptera and 8 Parasitic Hymenoptera ; from France.

THE INDIAN SPECIES OF *CALANDRA*, F. (COL. CURCUL.).

By Sir Guy A. K. Marshall. E.M.N.

The grain weevils of the genus *Calandra*, F., are more strongly represented in the Oriental Region than in any other part of the world. In addition to the eight Indian species dealt with in the following key, four others have been recorded from further east, and some ten additional undescribed species are known to me, mostly from the Malayan Subregion.

Key to the Indian Species of Calandra.

1 (2). Rostrum without any sub-basal dilatation, but narrowing from base to middle, the downward portion of the scrobes actually touching the eyes...*linearis*, Hbst.

2 (1). Rostrum with a sub-basal dilatation above the antennae, scrobes not reaching the eyes.

3 (4). Wings rudimentary; metepisterna bearing only a single row of punctures; elytra with oblique shoulders, the intervals much broader than the striae, convex, impunctate (except int. 1)..................................*granaria*, L.

4 (3). Wings functional; metepisterna with at least two rows of punctures; elytra with distinct rounded shoulders, the intervals much narrower than the striae, or else deeply punctate.

5 (14). Pygidium without a median carina; elytra without any deep subapical depression or prominences.

6 (11). Pronotum without any true median carina, the punctures round and not longitudinally confluent.

7 (10). Pronotum with a distinct shoulder behind the very deep subapical constriction.

8 (9). Punctures in the middle of the disk of the pronotum small, round and separated, the intervals flat; elytra (when mature) black with four red spots; setae peg-like..*oryzae*, L.

9 (8). Punctures on the disk of the pronotum much larger and reticulate (often pentagonal or hexagonal), the intervals all narrowly carinate; elytra red-brown, with all the margins often narrowly blackish; setae broadly spatulate (fig. 1)...*vateriae*, sp. n.

10 (7). Pronotum without any shoulder behind the shallower subapical constriction, its shape more narrowly conical; all intervals on elytra narrowly carinate (fig. 2)...*conicollis*, sp. n.

11 (6). Pronotum with a distinct median carina.

12 (13). Pronotum with longitudinal undulating carinulae; sub-basal dilatation of rostrum narrower than the head across the base of the eyes; rostrum of female with rows of distinct punctures; elytra at the shoulders not wider than the prothorax ....*rugicollis*, Casey

13 (12). Punctures on pronotum reticulate, like honeycomb; sub-basal dilatation of rostrum as wide as head at base of eyes; rostrum of female almost impunctate (except at base); elytra wider at the shoulders than the prothorax and narrowing much more rapidly behind......................... *erosa*, sp. n.

14 (5). Pygidium with a median carina; elytra with a deep subapical depression having a rugose prominence above it on intervals 5–7 and another beside it on interval 3...*glandium*, Mshl.

Calandra vateriae, sp. n. (fig. 1).

♂♀. Colour uniform red-brown, with the margins of the elytra often narrowly blackish.

Rostrum of ♂ with the usual rows of coarse punctures, the median line narrowly carinate on the basal two-thirds, the two adjoining intervals on each side set with low shiny granules ; the sub-basal dilatation narrower than the width of the head across the base of the eyes, with broad sulci containing large deep punctures and separated by narrow intervals ; rostrum of ♀ with the narrow anterior portion smooth, with the punctures smaller but strong. *Prothorax* longer than broad, rounded laterally, widest at one-fourth to one-third from the base, with a deep subapical constriction extending more shallowly across the dorsum, the apical margin shallowly sinuate ; the dorsum slightly convex longitudinally, the apical collar being below the level of the disk (especially in ♂), with large reticulate punctures, like honeycomb, many being pentagonal or hexagonal, with the intervals narrowly carinate, without any smooth median line or carina. *Elytra* not wider at the shoulders than the widest part of the prothorax and gradually narrowing posteriorly ; intervals 1 and 3 with large quadrate punctures almost or quite as large as those in the adjoining sulci, the remaining intervals narrowly and sinuously carinate, the alternate ones bearing a row of short stout erect spatulate yellow setae. *Pygidium* set with large deep reticulate punctures without any median carina and bearing strongly spatulate erect setae.

Length 3·5 mm., breadth 1·3 mm.

S. India : Mangalore, 4 ♂ 7 ♀, bred from seeds of the Indian copal tree (*Vateria indica*), x.1930 (*Miranda*).

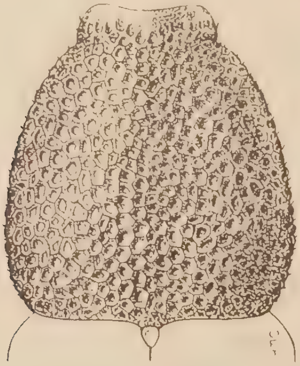

Fig. 1. *Calandra vateriae*, sp. n., prothorax.

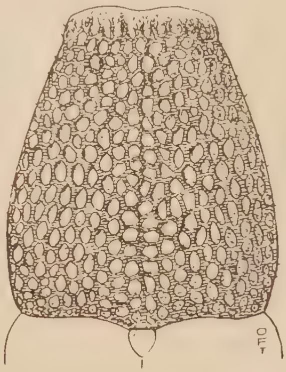

Fig. 2. *Calandra conicollis*, sp. n., prothorax.

Calandra conicollis, sp. n. (fig. 2).

♂♀. Colour uniform dull black.

Rostrum of ♂ as in *C. vateriae*, sp. n. ; that of ♀ with the narrow part opaque, with rather irregular rows of distinct elongate punctures. *Prothorax* comparatively narrow and elongate, subconical, widest close to the base, the sub-apical constriction unusually shallow, so that there is no shoulder behind it ; the dorsum flat longitudinally in the middle, with uniformly reticulate punctures, the intervals narrowly carinate, without any smooth median line or carina. *Elytra* as wide at the shoulders as the widest part of the prothorax, suboblong, less narrowed behind than usual ; interval 1 with a row of quadrate punctures as large as those in the sulci, but all the other intervals narrowly carinate and without punctures, almost equally raised, the alternate ones bearing a row of short erect peg-like setae. *Pygidium* with large reticulate punctures without any median carina and set with short subrecumbent peg-like setae.

Length 3·1–4·0 mm., breadth 1·1–1·3 mm.

ANDAMAN IS.: Middle Andaman, Long I., 2♂ 6♀, bred from unknown seeds, 1930 (*C. F. C. Beeson*).

Calandra erosa, sp. n.

♂♀. Colour dull black, with the legs, antennae and apex of rostrum red-brown.

Rostrum with the sub-basal dilatation about as wide as the head at the base of the eyes and rather longer than usual, the length from the base to the widest part being greater than the longitudinal diameter of an eye ; the narrow anterior part of rostrum of ♂ curved, with four dorsal coarsely-punctate sulci on its basal half, these being continued to the apex as rows of punctures, the intervals without rows of granules, the median line carinate on the basal half only ; narrow part of rostrum of ♀ rather shiny, impunctate except close to its base. *Prothorax* longer than broad, slightly rounded laterally, widest near the base, with a deep subapical constriction which becomes very shallow or obsolete dorsally ; the dorsum almost flat longitudinally in the middle, with coarse subreticulate punctures which vary a good deal in size and have their narrow intervals somewhat uneven, and with a well-marked complete median carina. *Elytra* distinctly wider at the shoulders than the widest part of the prothorax and narrowing rapidly behind, the sutural area depressed as far as interval 3 on each side, the sulci with very large subquadrate punctures ; the alternate intervals somewhat more elevated, especially 3 and 5, subcarinate and bearing a row of separated oval setigerous punctures, which are much smaller than those in the sulci ; the setae very short, stout, suberect. *Pygidium* with coarse subreticulate punctures and short peg-like suberect setae, without any median carina.

Length 3·5–5·0 mm., breadth 1·1–1·6 mm.

BURMA: Ruby Mines, 1♂ 1♀ (*Doherty* type). ASSAM: Sadiya, 1♀, v.1930 (*T. B. Fletcher*).

In the Catalogus Coleopterorum, Pars 149, the present genus is listed under the name *Sitophilus*. The writers who use this name appear to have overlooked the fact that the International Commission on Zoological Nomenclature is prepared to make provision for the preservation of well known names of wide currency, a change in which would cause unnecessary confusion. *Calandra* is an obvious case of this kind, and application is being made for its establishment as the generic name of the grain weevils. Unless and until the proposal has been rejected, it is clearly undesirable that the name *Sitophilus* should be used.

It may be noted that in the same Catalogue *Calandra sculpturata*, Gyll., is recorded as an Indian species, although it was pointed out in 1920 (Bull. Ent. Res. **11,** p. 277, note) that the name is really applicable to an African species. Further, *Calandra mexicana*, Champ., has been sunk as a synonym of *Polytus mellerborgi*, Boh., with which it is in no way related ; it is a good species of *Calandra*.

FURTHER NOTES ON THE FOOD-PLANTS OF NIGERIAN INSECTS. V.

By F. D. Golding, M.A., F.R.E.S.

In 1927, 1931, 1935 and 1937 the writer published four papers on the food-plants of Nigerian insects in this *Bulletin* (**18,** pt. 1 ; **22,** pt. 2 ; **26,** pt. 2 ; and **28,** pt. 1). The present paper contains additional data obtained between April 1936 and October 1939.

The writer wishes to acknowledge his indebtedness to the Imperial Institute of Entomology and the specialists of the Department of Entomology in the British Museum for identifying the insects mentioned and to Mr. J. H. MacKay, Nigerian Forest Service, for determining a number of the food-plants.

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
LEPIDOPTERA				
PIERIDAE—				
Catopsilia florella, F. ...	*Cassia siamea*	Leaves	April	Mamu, larvae
NYMPHALIDAE—				
Hypolimnas misippus, L.	*Amaranthus caudatus*	,,	,,	Ibadan, ,,
Pseudacraea lucretia, Cram.	*Malacantha alnifolia*	,,	,,	Olokemeji, larvae
Leucosticha daedalus, F....	*Combretum racemosum*	,,	Feb.	Ibadan, ,,
ARCTIIDAE—				
Rhodogastria leucoptera, Hmps.	*C. mucronatum*	,,	,,	,, ,,
Creatonotus marginalis, Wlk.	*Newbouldia laevis*	,,	March	,, ,,
AGARISTIDAE—				
Aegocera rectilinea, Boisd.	*Boerhaavia diffusa*	,,	April	,, ,,
A. menete, Cram. ...	*Cochlospermum tinctorium*	,,	May	Zaria, ,,
LYMANTRIIDAE—				
Naroma signifera, Walk.	*Ficus capensis*	,,	March	Ibadan, ,,
Olapa tavetensis, Holl. ...	*Sterculia tragacantha*	,,	June	,, ,,
NOCTUIDAE—				
Laphygma exempta, Wlk.	*Zea mays*	,,	May	Ibadan & Onitssa, larvae
Cirphis loreyi, Dup. ...	*Sorghum vulgare*	,,	Sept.	Ibadan, larvae
Prodenia litura, F. ...	*Amaranthus caudatus*	,,	April	,, ,,
Ophiuche conscitalis, Walk.	*Desmodium mauritianum*	,,	Aug.	,, ,,
Characoma stictigrapta, Hmps.	*Theobroma cacao*	Borer in young shoots	May	,, ,,
NOCTUIDAE—				
Hyblaea puera, Cram. ...	*Newbouldia laevis*	Leaf-roller	March	,, ,,
Hypocala rostrata, F.	*Diospyros monbuttensis*	,, ,,	April	,, ,,
Brithys pancratii, Cyr. ...	*Crinum giganteum*	Leaves	March	,, ,,

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
	LEPIDOPTERA—*Cont.*			
NOCTUIDAE—*cont.*				
Achaea lienardi, Boisd.	*Monodora tenuifolia*	Leaves	April	Olokemeji, larvae
	Bridelia ferruginea	,,	,,	,, ,,
A. faber, Holl.	*Celtis prantlii*	,,	,,	,, ,,
Cyligramma simplex, Grünb.	*Anona senegalensis*	,,	May	Zaria, ,,
Busseola fusca, Full. ...	*Pennisetum typhoides*	Stem-borer	June	,, ,,
Heliothis armigera, Hübn.	*Gossypium hirsutum*	Bolls	Aug.	,, ,,
Earias biplaga, Wlk. ...	*Sterculia tragacantha*	Leaves	March	Ibadan, ,,
Dermaleipa parallelipipeda, Guen.	*Citrus paradisi*	Fruits	May	,, adults
Lophotavia incivilis, Wlk.	*Mangifera indica*	,,	,,	,, ,,
Nagia natalensis, Hmps.	*Mangifera indica*	,,	,,	,, ,,
SPHINGIDAE—				
Platysphinx phyllis, Roth.	*Lonchocarpus sericeus*	Leaves	March	,, larvae
Polyptychus carteri, Butl.	*Cola nitida*	,,	Oct.	,, ,,
Herse convolvuli, L. ...	*Ipomoea batatas*	,,	Nov.	Ilorin, ,,
Nephele aequivalens, Wlk.	*Funtumia elastica*	,,	April	Olokemeji, ,,
Deilephila nerii, L. ...	*Sarcocephalus russegeri*	,,	,,	,, ,,
EUPTEROTIDAE—				
Phiala hologramma, Aur.	*Theobroma cacao*	,,	July	Ibadan, ,,
LASIOCAMPIDAE—				
Gonometa nysa, Druce ...	*Mangifera indica*	,,	Jan.	,, ,,
Trabala charon, Druce ...	*Combretum mucronatum*	,,	Aug.	,, ,,
Leipoxais rufobrunnea, Strand	*Ricinus communis*	,,	,,	,, ,,
L. marginepunctata, Holl.	*Combretum mucronatum*	,,	Nov.	,, ,,
Chrysopsyche mirifica, Butl.	*Alchornea cordifolia*	,,	Oct.	,, ,,
SATURNIIDAE—				
Bunaea alcinoë, Cram. ...	*Manihot utilissima*	,,	May	,, ,,
PYRALIDAE—				
Thliptoceras octoguttalis, Feld.	*Coffea* sp.	Berries	Aug.	,, ,,
Pimelephila ghesquierei, Tams	*Elaeis guineënsis*	Young leaves	Nov.	Warri, ,,
Sylepta retractalis, Hmps.	*Deinbollia pinnata*	Leaves	March	Ibadan, ,,
S. derogata, F.	*Hibiscus esculentus*	Leaf-roller	July	Zaria, ,,
Lamprosema indicata, F.	*Phaseolus lunatus*	,, ,,	Jan.	Ibadan, ,,
Margaronia ectargyralis, Hmps.	*Ficus thonningii*	,, ,,	March	,, ,,
TINEIDAE—				
Phthorimaea heliopa, Lw.	*Nicotiana tabacum*	Stem-borer	Oct.	Zaria and Ogbomosho, larvae
Setomorpha rutella, Zell.	*Nicotiana tabacum*	Seeds	June	Oshogbo, larvae
GRACILARIIDAE—				
Acrocercops chalybophanes, Meyr.	*Coffea* sp.	Leaf-miner	Jan.	Ibadan, larvae

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
	RHYNCHOTA.			
Pentatomidae—				
Durmia haedula, St. ...	*Eleusine coracana*	Seeds	April	Ibadan, adults
Acrosternum punctato-rugosum, St.	*Citrus paradisi*	Fruits	May	,, ,,
Bathycoelia thalassina, P.B.	*Citrus sinensis*,	,,	April	,, ,,
	Theobroma cacao	Pods	Oct., Nov.	,, adults and nymphs
Piezosternum fallax, F.	*Theobroma cacao*	,,	Aug.	Owena, adults
Levida punctata, P. B. ...	*Stachytarpheta angustifolia*	Flower spikes	April	Ibadan, ,,
Caura pugillator, F. ...	*Ricinus communis*	Petioles and green fruits	,,	,, ,,
Halyomorpha annulicornis, Sign.	*Duranta plumieri*	Fruits	,,	,, ,,
Aspavia hastator, F. ...	*Paspalum scrobiculatum*, var. *polystachyum*	Seeds	June, Sept.	,, ,,
Coreidae—				
Pendulinus devastans, Dist.	*Caesalpinia pulcherrima*	Green pods	Aug.	,, adults and nymphs
Leptoglossus membranaceus, F.	*Citrus nobilis*, var. *deliciosa*	Fruits	April, May	Ibadan, adults
	Mangifera indica,	,,	,,	,, ,,
	Citrullus vulgaris	,,	May, June	,, adults and nymphs
Lygaeidae—				
Paromius gracilis, Ramb.	*Eleusine coracana*	Seeds	April	Ibadan, adults
Cercopidae—				
Locris maculata, F. ...	*Paspalum scrobiculatum*, var. *polystachyum*	Leaves	Oct.	,, ,,
Capsidae—				
Helopeltis bergrothi, Reut.	*Solanum verbascifolium*,	Shoots and leaves	,,	,, adults and nymphs
	S. torvum,	Leaves	Nov.	Ibadan, nymphs
	Paullinia pinnata,	,,	,,	,, ,,
	Mucuna aterrima,	,,	,,	,, adults and nymphs
	Vigna unguiculata,	,,	Oct.	Ibadan, adults and nymphs
	Cajanus cajan,	Leaves and stems	Oct., Nov.	Ibadan, adults and nymphs
	Jussiaea sp., prob. *linifolia*,	Leaves	Feb.	Ibadan, adults and nymphs
	Acalypha spp.	,,	Sept., Oct.	Ibadan, adults and nymphs
	COLEOPTERA			
Cetoniidae—				
Incala schoutedeni, Moser	*Mangifera indica*	Fruits	April	Ibadan, adults
Plaesiorrhina recurva, F.	*M. indica*	,,	,,	,, ,,
Heterorrhina suturalis, F.	*M. indica*	,,	,,	,, ,,
Pachnoda cordata, Drury	*M. indica*	,,	,,	,, ,,

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
COLEOPTERA—*Cont.*				
Coccinellidae—				
Epilachna bombarti, Muls.	*Vernonia amygdalina*	Leaves	June	Ibadan, adults
E. chrysomelina, F. ...	*Citrullus vulgaris*	,,	,,	,, ,,
Languridae—				
Anadastus cuprea, Arr.	*Pennisetum purpureum*	Stem-borer	Feb.	,, larvae
Galerucidae—				
Pachytoma gigantea, Illig.	*Triumfetta rhomboidea*	Leaves	April	Bode Sadu, adults and larvae
Hemiphracta lurida, All.	*Ficus capensis*	,,	March	Ibadan, larvae
DIPTERA				
Stratiomyiidae—				
Hermetia pennicornis, Bezzi	*Elaeis guineënsis*	Stalks of female inflorescences	Feb.	,, ,,
Trypetidae—				
Ceratitis rosa, Karsch ...	*Ximenia americana*	Seeds	June	Zaria, larvae
ORTHOPTERA				
Acrididae—				
Phymateus karachi, Bol.	*Thevetia neriifolia*	Leaves	July	Kano, nymphs
Cyrtacanthacris aeruginosa unicolor, Uv.	*Gossypium barbadense*	,,	Oct.	Ibadan, nymph
Morphacris fasciata, Thnbg., ab. *sulcata*, Thnbg.	*Zea mays*	,,	May June, Sept.	,, ,, ,, adults
Catantops simplex, Uv.	*Theobroma cacao*,	,,	Aug.	Owena, ,,
	Solanum verbascifolium	,,	,,	,, nymphs
Stenocrobylus festivus, Karsch	*Ficus capensis*	,,	June	Ibadan, ,,
Atractomorpha gerstaeckeri, I. Bol.	*Amaranthus caudatus*	,,	Feb.	,, ,,
Catantopsilus taeniolatus, Karsch	*Aspilia latifolia*	Flower	Jan.	,, ,,
Holopercna gerstaeckeri, I. Bol.	*Costus afer*	Leaves	Aug.	,, adults
Taphronota ferruginea, F.	*Anthocleista nobilis*	,,	June	,, adults and nymphs
T. amaranthina, Bol. ...	*Anthocleista nobilis*,	,,	,,	Ibadan, adults and nymphs
	Rauwolfia vomitaria	,,	,,	Ibadan, nymph
Abisares viridipennis, St.	*Triumfetta cordifolia*, var. *hollandii*	Young leaf	May	,, adult

ON SOME PARASITES AND HYPERPARASITES OF *ARTONA CATOXANTHA*, HAMPS.

By Ch. FERRIÈRE, D.Sc.,

Imperial Institute of Entomology.

The Institute of Plant Diseases at Buitenzorg has been engaged in the study of the well-known coconut pest, *Artona catoxantha*, Hamps., and has sent to the Imperial Institute of Entomology a large and very interesting collection of its parasites and hyperparasites. We understand that Dr. J. v. d. Vecht is preparing a paper on the ecology of this Zygaenid. To complete his studies on the life-histories of all these parasites we have been asked to make a special study of the Chalcids.

Besides the material received from Java and bred by Dr. J. v. d. Vecht, we have also studied all the specimens of Chalcids bred in relation with *Artona catoxantha* and sent in previous years from Java by Mr. T. H. C. Taylor, and from Malaya by Mr. G. H. Corbett and Mr. B. A. R. Gater.

In this large material we have found the following species :

Species	Number of specimens from	
	Java	Malaya
Fam. CHALCIDIDAE		
Brachymeria punctiventris, Cam.	12	16
Brachymeria lugubris, Walk.	3	3
Brachymeria apicicornis, Cam.	1	—
Stomatoceras sp.	—	1
Dirhinus banksi, Rohwer	1	—
Fam. EURYTOMIDAE		
Eurytoma albotibialis, Ashmead	56	23
Fam. EUPELMIDAE		
Eupelmus catoxanthae, sp. n.	13	8
Anastatoidea brachartonae, Gahan	42	4
Fam. EULOPHIDAE		
Neoplectrus bicarinatus, sp. n.	48	—
Neoplectrus maculatus, sp. n.	22	—
Euplectromorpha artonae, sp. n.	23	—
Euplectromorpha viridiceps, sp. n.	51	10
Pleurotropis detrimentosus, Gahan	47	27
Pleurotropis ptychomyiae, sp. n.	66	18
Tetrastichus sp.	—	9
Syntomosphyrum zygaenarum, Ferr.	9	—
and var. *nigricoxis*, nov.	21	—
Syntomosphyrum obscuriceps, sp. n.	42	8
Melittobia hawaiiensis, Perkins	76	175

It will be seen that most species have been found both in Malaya and in Java. Two species from Malaya have been received in too small numbers to be named. It seems that only the EUPLECTRINI, *Neoplectrus* and *Euplectromorpha*, are always primary parasites of *Artona* ; *Eurytoma* and *Eupelmus* can be either primary or secondary parasites ; all the other species are hyperparasites, either in the Tachinids, *Ptychomyia* and *Cadurcia*, or in the Ichneumonid, *Goryphus* sp., or in the Braconid, *Apanteles artonae*, Rohw.

In the following pages only the new species and varieties, as well as the previously unknown male of *Anastatoidea brachartonae*, Gah., are described.

Eupelmus catoxanthae, sp. n. (fig. 1).

♀. Dark green, almost black or aeneous on mesonotum and scutellum, more bluish-green on cheeks, temples, sides of propodeon and base of abdomen ; face varied green and aeneous ; abdomen aeneous black or more or less cupreous, often greenish at tip. Antennae with the scape yellow, the flagellum black with greenish reflection on the funicle and blue-violaceous reflection on the pedicel. Legs black with faint metallic reflections, trochanters, end of middle and hind femora, fore tibiae (except a brownish band), middle tibiae almost entirely, end of hind tibiae and all tarsi, brownish-yellow. Wings slightly yellowish, nerves light brown. Ovipositor narrowly black at base, broadly white in the middle and brown at tip.

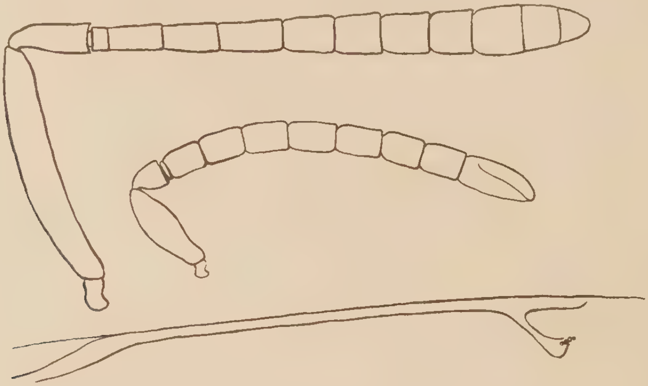

Fig. 1. *Eupelmus catoxanthae,* sp. n. : antenna ♀ (above) ; antenna ♂ and wing nervature.

Head transverse, narrow, eyes short-oval ; lateral ocelli farther distant from each other than from the front ocellus and as near to the eye-margin as their own breadth. Vertex finely transversely striate. Face rugulose, antennal furrow short, shagreened ; cheeks finely striate. Antennae inserted near the sides of the clypeus ; scape slightly curved, short ; pedicel about twice as long as broad or more, annellus broader than long, 1st funicle joint much longer than broad, the following ones gradually shorter and broader, the 6th subquadrate, the 7th a little broader than long. Mesonotum finely reticulate, dull, slightly striate in front and shagreened on the sides, and entirely covered with thick white ciliae, more or less in regular rows. Mesopleurae finely shagreened, more strongly on the hind third. Scutellum more finely sculptured than the mesonotum, with weaker and more scattered ciliae. Propodeon short, smooth in the middle, shagreened on the sides. Wings with the marginal vein about six times as long as the stigmal and postmarginal veins, which are subequal in length. Hind femora a little thickened. Abdomen about as long as the thorax, shagreened above, smooth at base. Ovipositor as long as 40 to 45 per cent. of the length of the abdomen and as long as $\frac{4}{5}$ of the hind tibiae.

♂. Dark green, more or less blackish, abdomen aeneous black ; base of abdomen and propodeon shining green ; antennae and legs black, only the tip of fore and middle tibiae, the anterior tarsi and the middle and hind metatarsi, yellow. Scape short, slightly thickened in the middle, pedicel scarcely longer than broad, funicle joints subequal in length, longer than broad and covered with a dense ciliation. Abdomen small, triangular, narrower and shorter than the thorax.

Length, ♀ 1·5–3 mm. ; ♂ 1·3–1·5 mm.

East Java : Res. Madioen, Patjitan, 6 ♀ 1 ♂, 1939, ex *Artona catoxantha* pupa ; Middle Java : Res. Semarang, 4 ♀ 2 ♂, 1939, ex *Apanteles artonae* (*Dr. J. v. d. Vecht*).

Malaya : Kuala Depang, 1 ♀, vii.1925, ex *Artona catoxantha* ; Banting, 2 ♀, iv.1932, ex *Apanteles artonae* ; Menglembu, 1 ♀ 3 ♂, iv.1934, ex *Artona catoxantha* pupa ; Menglambu, 1 ♀, iv.1934, ex *Ptychomyia remota* (*G. H. Corbett*).

This species is, like several other *Eupelmus* spp., both a primary and a secondary parasite ; it will probably be found attacking other insects in Java and Malaya.

Eupelmus javae, Girault, parasite of *Araecerus fasciculatus* in the pods of *Tephrosia*, although closely related, is quite distinct. The body is more elongate and especially the ovipositor is much longer, being longer than the hind tibiae and longer than half the length of the abdomen ; the ciliation on the mesonotum is also finer and more sparse.

Eupelmus tachardiae, How., from India and Ceylon, is much more closely related, but may be distinguished by its shorter ovipositor which is scarcely longer than half the length of the hind tibiae and than ⅓ of the abdomen. Moreover the hind tibiae of these last two species is never black.

Eupelmus orientalis, Ferr., another species from Java, bred from galls on roots of *Ficus*, has the antennae and legs yellow, with only the coxae black, and the antennal club and femora more or less brownish.

We may add that *Eupelmus pictipennis*, Six, is not from Java, as indicated in the Genera Insectorum, but has been collected in Utrecht, Holland ; further it is not a *Eupelmus* but an Encyrtid, and is, according to the description and figures, the same as *Anabrolepis zetterstedti*, Westw.

Anastatoidea brachartonae, Gahan (fig. 2).

The male of this species had never been found or recognised before and is here described.

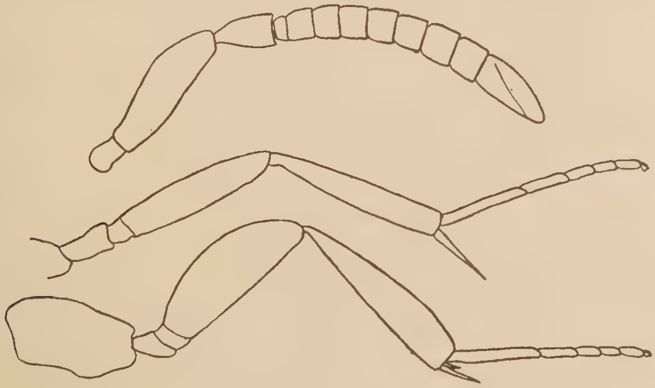

Fig. 2. *Anastatoidea brachartonae*, Gahan : ♂ antenna, middle leg and hind leg.

♂. Body bluish green with the frons, the parapsides partly, the scutellum and the abdomen, except base, aeneous black. Antennae and legs entirely black, only the first two joints of the middle and hind tarsi white.

Head with the vertex narrow and densely ciliate ; fronto-vertex a little more than twice as long as broad ; lateral ocelli near the eye-margins and nearer to each other than to the front ocellus ; scrobes deep and smooth, limited above by a distinct transverse carina. Eyes large, oval, ciliate. Antennae inserted near the sides of the clypeus ; scape short, thickened in the middle, about three times as long as its median breadth ; pedicel narrow, elongate, almost twice as long as broad ; annellus short, transverse ; funicle joints gradually broader towards the tip, all broader than long ; club truncate, about as long as two preceding joints together.

Mesonotum densely punctate ; parapsidal furrows deep in front, broader and shallow behind ; scutellum finely shagreened, smooth at tip ; propodeon smooth, short, with a median carina. Wings hyaline ; marginal vein about three times as long as the stigmal vein, postmarginal vein a little shorter than the marginal vein. Legs strong, all femora more or less thickened ; middle tibiae narrow, the spur almost as long as the metatarsus ; hind tibiae somewhat broadened and flattened, but without flange along the posterior margin. Abdomen oval, shorter than the thorax.

Length, 1·5–2·5 mm.

Series of males and females were obtained from :—

M. JAVA : Res. Kedoe, 3 ♀ 31 ♂, 1939, ex *Apanteles artonae* ; 1 ♂, ex *Ptychomyia* sp. ; 5 ♀, ex Tachinid ; 2 ♀, ex *Goryphus* sp. (*Dr. J. v. d. Vecht*).

As can be seen here, this species is generally, if not always, a hyperparasite.

The male is very different from the female and is similar in general aspect to the males of *Eupelmus* spp. As we have already pointed out in studying another species, *A. seyrigi*, Ferr., from Madagascar, the males of *Anastatoidea* can be recognised by the following characters : Fronto-vertex narrow, longer than broad ; antennae short, scape thickened, funicle joints subquadrate or transverse, club truncate ; hind legs distinctly thickened, the tibiae slightly flattened.

EUPLECTRINI.

This tribe, which seems to be represented by many more species in the tropical countries than in the temperate regions (we are studying a large number of species from South Asia and Africa still undescribed), may be divided into several groups which could be considered as distinct genera. For the present we recognise three genera, mentioned in the following key.

1. Propodeon with two longitudinal carinae forming a median area...................... *Neoplectrus*, gen. nov.
–. Propodeon with only one median carina..2
2. Scutellum with distinct lateral furrows........................*Euplectromorpha*, Gir.
–. Scutellum without lateral furrows..................................*Euplectrus*, Westw.

Neoplectrus, gen. nov.

Vertex broad, not distinctly margined behind. Eyes closely ciliate. Antennal furrow limited by a narrow black line in form of an inverted V, the point below the front ocellus. Prothorax large, margined in front. Scutellum almost flat, with thin longitudinal furrows. Propodeon with a distinct median area, limited on each side by a carina. Abdomen short, oval ; petiole very short, transverse. Spur of hind tibiae reaching the middle of the second tarsal joint. Body generally entirely or almost entirely yellow.

Neoplectrus bircarinatus, sp. n. (figs. 3, 4).

♀♂. Body yellow, with only the transverse carina on the pronotum, the lines on the face and the ovipositor black ; the base of mesonotum and scutellum, the propodeon and the abdomen are more orange-yellow. Antennae brown, scape and pedicel yellow. Legs entirely yellow. The male has the abdomen more or less brown or black on the posterior half ; the abdomen of some females has also some faint brown markings above.

♀. Head transverse, vertex broad ; ocelli small, the lateral ocelli nearer to the front ocellus than to the eye-margins. Eyes with close and rather long ciliation. Antennae with the scape narrow, reaching below the front ocellus ; pedicel one and a half times longer than broad ; first funicle joint longer than the pedicel, about twice as long as broad, the following joints shorter, but all longer than broad ; club entire, not broader and distinctly longer than the preceding joint. Pronotum large, not much shorter than the mesonotum, the lateral margins slightly converging in front, the transverse carina strong. Mesonotum shagreened, like the pronotum, with complete parapsidal furrows. Scutellum almost smooth, broadening behind. Propodeon smooth, with four carinae, the two middle ones delimiting a rectangular area. Wings large ; marginal vein longer than the submarginal vein ; stigmal vein narrow, shorter than the postmarginal vein. Hind legs strong. Abdomen a little narrower and shorter than the thorax, pointed behind. Ovipositor scarcely protruding.

♂. Quite similar but smaller, antennae more ciliate, abdomen very short.

Length, ♀ 1·3–2 mm. ; ♂ 0·8–1·3 mm.

JAVA : Goemingsir, 7 ♀ 2 ♂, vii.1937 ; 16 ♀ 23 ♂, 1939 ; all ex larvae of *Artona catoxantha* (*Dr. J. v. d. Vecht*).

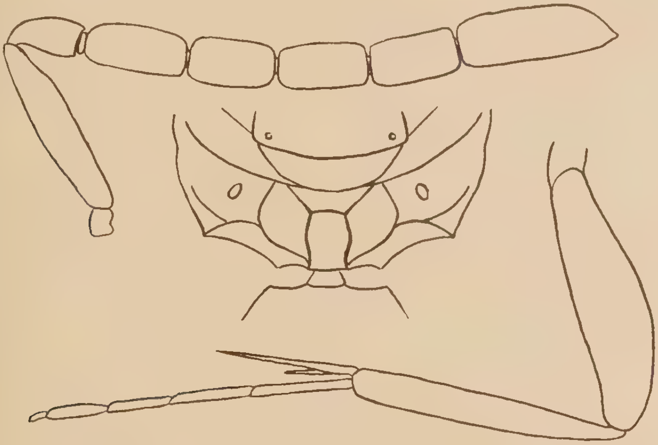

Fig. 3. *Neoplectrus bicarinatus*, sp. n., ♀ ; antenna, propodeon and hind leg.

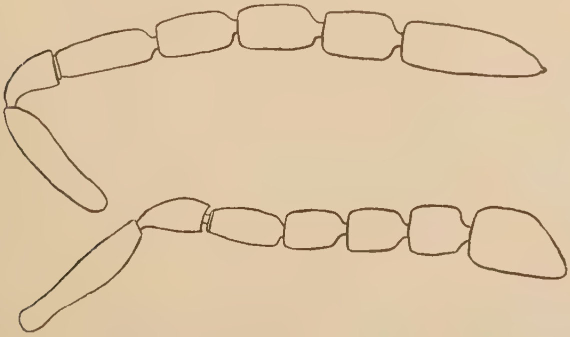

Fig. 4. Antennae ♂ of *Neoplectrus bicarinatus*, sp. n. (above) and *N. maculatus*, sp. n. (below).

Neoplectrus maculatus, sp. n. (fig. 4).

♀♂. This species is in general aspect very similar to *N. bicarinatus*. The female is generally lighter in colour, the carina on the pronotum not or indistinctly black, the thorax more uniformly orange-yellow, the abdomen sometimes more or less brownish on the sides. The males are recognised at once in having the terminal third of the middle tibiae black. But the most important difference between these two species is in the form of the antennae : in *N. maculatus* they are shorter, with the fourth funicle joint subquadrate : the club is specially short, broader than the funicle and broadly truncate.

Length, ♀ 1·3–1·5 mm. ; ♂ 0·9–1·3 mm.

MIDDLE JAVA : 1 ♀ 21 ♂, 1939, ex *Artona catoxantha* larvae (*Dr. J. v. d. Vecht*).

CEYLON : Passara, 1 ♀ 1 ♂, vi.1929 (*Dr. J. C. Hutson*) ; 2 ♀ 1 ♂, ix.1931 (*C. B. R. King*), ; all ex *Natada nararia*.

Euplectromorpha artonae, sp. n.

♀. Head and thorax black, the vertex with very slight dark greenish reflection ; abdomen black with a rounded yellow spot on basal half. Antennae brown, scape whitish. Legs yellow, coxae black, hind femora brownish above.

Head smooth and shining, with long scattered black ciliae ; eyes not ciliate, oval ; lateral ocelli at shorter distance from the front ocellus than from the eye margin. Vertex carinated behind the ocelli. Antennae with the scape narrow, short ; pedicel longer than broad ; first funicle joint a little longer than the pedicel ; the following joints not much shorter and all longer than broad ; club somewhat longer than the preceding joint. Pronotum short, narrowed in front, the anterior portion rugulose, separated from the smooth hind margin by a transverse carina. Mesonotum and scutellum shagreened ; scutellum with the lateral furrows distinct, rather broad and slightly crenulated, ending in a strong transverse furrow along the hind margin. Propodeon finely punctate, with a strong median carina. Wings large ; marginal vein about four times as long as the stigmal vein ; postmarginal vein almost twice as long as the stigmal vein. Hind legs strong, the femora a little thickened, the longer spur of the hind tibiae about as long as the metatarsus with half the following joint. Abdomen short, oval, shorter than the thorax, the petiole very short, broader than long.

Length, 1·2–1·7 mm.

JAVA : Buitenzorg, 6 ♀, 1926 (*T. H. C. Taylor*) ; 17 ♀, 1939 (*Dr. J. v. d. Vecht*) ; all ex *Artona catoxantha*.

Euplectromorpha viridiceps, sp. n.

♀♂. Head dark green, occiput black ; thorax quite black ; abdomen black, yellowish-brown at base above and below. Antennae brown, scape yellow, pedicel light brown. Legs yellow, hind coxae black, hind femora slightly brownish above.

♀. Head finely shagreened, shining, frons and vertex covered with short greyish ciliae. Eyes oval, finely and densely ciliate. Lateral ocelli as far distant from the front ocellus as from the eye-margin. Vertex not margined. Antennae with the scape narrow, pedicel short, not much longer than broad ; first funicle joint about twice as long as the pedicel, the following joints shorter, but all longer than broad ; club not much longer than the preceding joint. Pronotum rounded in front, without transverse carina, rugulose above like the mesonotum. Scutellum and axillae smooth or very finely shagreened ; scutellum with lateral furrows, narrow but distinct. Propodeon smooth, with a strong median carina. Wings large ; marginal vein about three times as long as the stigmal vein and twice as long as the post-marginal vein. Hind legs strong ; spurs of hind tibiae as long as the metatarsus and not quite half the next tarsal joint. Abdomen oval, a little narrower and shorter than the thorax ; petiole elongate, about three times as long as broad and slightly longer than half the hind coxae.

♂. Similar, but the antennae with the scape broadened on apical half, the abdomen short oval, much shorter than the thorax, similarly petiolate.

Length, ♀ 1·5–2·5 mm. ; ♂ 1·2–1·8 mm.

MIDDLE JAVA : Various localities. 44 ♀ 7 ♂, 1939, (*Dr. J. v. d. Vecht*). MALAYA : Batu Gajah, 10 ♀, iii.1920 (*G. H. Corbett*). All ex *Artona catoxantha.*

This species is probably more widely distributed in the East than *E. artonae* ; we have also seen specimens from India, Dehra Dun, U.P., bred from *Dasychira* sp. on *Tectona grandis.*

Pleurotropis ptychomyiae, sp. n. (fig. 5).

♀♂. Body dark green, blackish on occiput and mesonotum, more shining bluish-green on vertex, hind margin of pronotum, propodeon and base of abdomen ; the rest of abdomen aeneous. Antennae brown, with faint greenish reflection on pedicel and funicle, scape yellow. Legs with coxae and femora greenish black, tibiae yellow, more or less brownish at base, tarsi whitish.

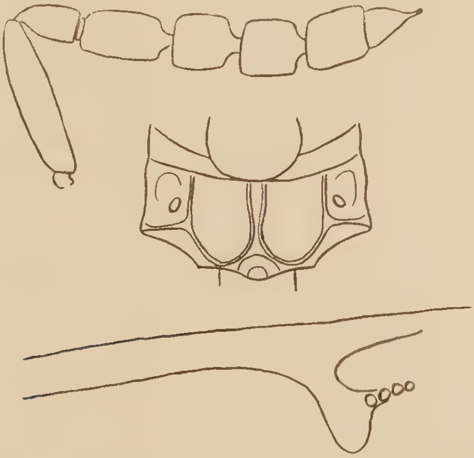

Fig. 5. *Pleurotropis ptychomyiae*, sp. n. ♀ ; antenna, propodeon and stigmal vein.

♀. Head sharply margined behind the vertex and eyes ; occiput excavated ; vertex broad, punctate, the lateral ocelli nearer to the eye-margin than to the front ocellus ; eyes shortly ciliate. Antennae with the scape narrow, short, not reaching to the front ocellus ; pedicel about one and a half times longer than broad ; one small annellus ; first funicle joint broader and longer than the pedicel, the two following joints still broader and subquadrate ; club with two joints, longer than the preceding joints, the terminal joint narrower and ending in a point. Pronotum very short, with a transverse carina before the hind margin. Mesonotum finely reticulate ; parapsidal furrows deep in front, ending behind in shallow impressions. Scutellum longitudinally striate all over. Propodeon smooth, the two median carinae running subparallel or converging a little behind and diverging only after the middle of the propodeon ; lateral carinae distinct. Wings large ; marginal vein longer than the submarginal ; stigmal vein short, subsessile ; postmarginal vein a little longer than the stigmal vein. Abdomen elongate and pointed behind, but not or little longer than the thorax, the second segment occupying almost half the length of the abdomen ; petiole broader than long, punctate, with two dorsal carinae. Ovipositor not protruding.

♂. Very similar but smaller ; antennae with the scape greenish black like the flagellum ; legs a little thicker, with the tibiae more broadly brown ; abdomen very short, the petiole subquadrate and densely punctate, dull, the rest of the abdomen smooth, not or little longer than broad.

Length, ♀ 1·4–2 mm. ; ♂ 0·9–1·6 mm.

East Java : Res. Madioen, Patjitan, 59 ♀ 3 ♂, 1939, ex *Ptychomyia* sp. ; 2 ♀, 1939, ex *Apanteles artonae* (*Dr. J. v. d. Vecht*) ; 2 ♂, 1926, secondary parasite of Zygaenids (*T. H. C. Taylor*).

Malaya : Kuala Depang, 2 ♀ 1 ♂, 23.vii.1925, ex *Ptychomyia remota* ; Kuala Langat, 3 ♀, 12.viii.1932, hyperparasite of *Artona catoxantha* ; 11 ♀, 1 ♂, 24.viii.1932, ex cocoon of *Ptychomyia remota* (*G. H. Corbett*).

Sumatra : Pematang Siantar, 14 ♀ 6 ♂, ix.1931, ex puparium of Tachinid ; 6 ♀, ix.1931, ex cocoons of *Apanteles* sp. (*R. I. Nel*) ; East Coast, Asahan, 3 ♀, 1934/36, hyperparasite of Gambir pest (on *Brachymeria euploeae* Westw.) ; 1 ♀, 1934/36, ex Tachinid puparium on Gambir (*F. Schneider*).

Syntomosphyrum obscuriceps, sp. n.

♀♂. Body orange-yellow ; head, except face and mouth, black with greenish reflection on vertex and frons ; occiput quite black ; sides of each abdominal segment with black markings. Antennae brown, pedicel lighter, scape yellow. Legs entirely yellow. The male is darker, with the pronotum and mesonotum black, the scutellum, axillae and propodeon dark brown ; abdomen dark, with only a yellow spot at base ; antennae and legs yellow, funicle and club light brown.

♀. Fronto-vertex broad, finely punctate ; occiput excavate and margined ; ocelli very small ; eyes short oval ; cheeks as long as half the length of an eye. Antennae with the scape narrow, short ; pedicel elongate, as long as half the scape ; three very short and transverse annelli ; funicle with three joints, the first longer than broad, but shorter than the pedicel, the two others subquadrate ; club elongate, pointed at tip, as long as or a little longer than two preceding joints together. Pronotum rather large, narrowed in front, without transversal carina. Mesonotum and scutellum finely shagreened, the scutellum without longitudinal furrows. Propodeon short, smooth, with a median carina and lateral carinae. Wings reaching a little beyond the tip of the abdomen ; marginal vein about as long as the submarginal vein ; stigmal vein short ; postmarginal vein not developed. Abdomen oval, as broad as or broader than the thorax and as long as head and thorax together. Ovipositor scarcely protruding.

♂. Smaller, the scape slightly broadened, funicle with four joints, all subquadrate and bearing some very long ciliae above ; club narrow and pointed. Abdomen narrower and not or scarcely longer than the thorax.

Length, ♀ 1·1–1·5 mm. ; ♂ 0·8–1·1 mm.

Java : Res. Madioen, Patjitan, 11 ♀, 1938, ex *Ptychomyia* sp. ; 4 ♀ 15 ♂, 1939, ex *Cadurcia* sp. ; Japara Kalibordah, 3 ♀ 1 ♂, vi.1939, ex *Artona catoxantha* pupa (*Dr. J. v. d. Vecht*) ; 8 ♀, 1926, secondary parasite of *Artona catoxantha* (*T. H. C. Taylor*).

Malaya : Banting, 6 ♀ 2 ♂, iv–v.1932, ex pupa of *Artona catoxantha* (*G. H. Corbett*).

BURMA: Yanaungungin Res., 3 ♀, 26.xii.1930, ex cocoon of Braconid (*D. J. Atkinson*).

CEYLON: Batticaloa, 28 ♀ 9 ♂, 25.x.1937, ex puparia of Diptera (*Dr. J. C. Hutson*).

A few other specimens varying somewhat in coloration are considered by Dr. v. d. Vecht as possibly biologically distinct. We do not find real morphological differences, except that the antennae are in average a little shorter, and we prefer to consider them only as varieties. They may be recognised as follows:—

var. a. ♀. Front yellowish, only vertex black; occiput dark with yellow spot in the middle; abdomen yellow with transverse dark stripes.

JAVA: Buitenzorg, 7 ♀ 5 ♂, iv.1940, ex *Apanteles artonae* (*Dr. J. v. d. Vecht*); 8 ♀, 1926, secondary parasite of *Artona catoxantha* (*T. H. C. Taylor*).

var. b. ♀. Head similar to var. a; thorax more brownish; abdomen dark, yellow at base only.

JAVA: Japara Kalibordah, 3 ♀ 1 ♂, vi.1939, ex *Artona catoxantha*, pupa (*Dr. J. v. d. Vecht*).

MALAYA: Banting, 1 ♀ 1 ♂, v.1932, ex *Artona* pupa; 3 ♀, iv.1932, ex cocoon on *Cocos nucifera* (*G. H. Corbett*).

Syntomosphyrum zygaenarum, Ferr.

Specimens identical with those described from Solomon Islands were received from: JAVA, 8 ♀ 1 ♂, 1926, ex *Artona catoxantha* (*T. H. C. Taylor*); SUMATRA, Res. Lampong, 2 ♀ 1 ♂, viii.1938, ex Tachinid (*Dr. J. v. d. Vecht*).

In the typical form the legs are entirely yellow, including coxae. All specimens obtained in Java by Dr. v. d. Vecht have the front and hind coxae, sometimes also the middle coxae, greenish black and the hind femora more or less brownish above. Otherwise they are entirely similar in the form of body and antennae with the type. To distinguish them from the typical form, we call them var. *nigricoxis*, nov. We have seen series from: MIDDLE JAVA: Res. Banjoemas, 2 ♀, 1939, ex *Apanteles artonae*; Res. Kedoe, 16 ♀ 1 ♂, 1939, ex *Goryphus* sp. EAST JAVA: Res. Madioen, Patjitan, 2 ♀, 1939, ex *Ptychomyia* sp. (*Dr. J. v. d. Vecht*); Soember Wadoeng n. Kalisat, 3 ♀, viii.1937, ex *Ferrisia virgata* (*H. J. de Fluiter*).

This species must not be confused with *Melittobia hawaiiensis*, Perk., which has also been obtained in large number from puparia of *Ptychomyia* in Java and Malaya, and from *Cadurcia* sp. in Sumatra. *M. hawaiiensis* has very similar short antennae, but differs by its flattened thorax and its black body, with coxae and femora of all legs black. All specimens examined in long series are females. The males, yellow, short-winged, with very large and broad scape, have only been seen in a series bred at Parit Buntar, Malaya, from pupae of *Megachile disjuncta*, F., by H. T. Pagden.

M. hawaiiensis, Perk., seems to be widely distributed as a parasite of nest-building Hymenoptera and of puparia of Muscid and Tachinid flies. Although all females are alike, it is possible that there are different biological races and that the parasites of Tachinids are parthenogenetic.

ON THE IDENTITY OF *APANTELES PRAEPOTENS*, HALIDAY (HYM. BRACON.).

By D. S. Wilkinson,
Imperial Institute of Entomology.

The information contained in this paper was prepared by me originally for inclusion in my forthcoming monograph on the palaearctic species of *Apanteles*, but, in view of the economic importance of the hosts of this particular species, it was deemed advisable to publish it immediately.

I am delighted to have such a suitable opportunity for acknowledging the assistance I have received from Mr. A. W. Stelfox, of the National Museum of Ireland. Mr. Stelfox has interested himself in my behalf on the question of the whereabouts of the Haliday types, and has lent me Haliday material for study ; and I am very considerably indebted to him for this help.

Apanteles praepotens, Hal.

Microgaster praepotens, Haliday, 1834, Ent. Mag., **2,** p. 252.

♀. Black ; front femora in at least apical half, front tibiae wholly, middle femora at extreme apex commonly, middle and hind tibiae in about basal three-fifths, and basal segment of all tarsi basally, red testaceous ; four anterior tarsi otherwise darkened, and their feet black ; palpi and tibial spurs pale ; wings hyaline ; about basal half or two-fifths of fore-wing, and about basal three-fifths of hind-wing, with the setae colourless, setae of fore-wing otherwise coloured, and of hind-wing commonly coloured ; costal veins (save at apex) red testaceous ; stigma, metacarp, 1st abscissa of radial, transverse cubital, and 2nd abscissa of cubital, brown ; remaining veins colourless or with some slight pigmentation ; stigma uniformly opaque.

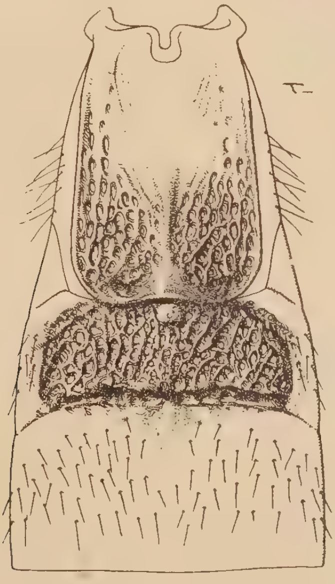

Fig. 1. *Apanteles praepotens*, Hal., basal tergites, ♀ (×80).

♂. Black ; front femora in apical half, front tibiae wholly, middle femora at extreme apex occasionally, and middle and hind tibiae in about basal half, red testaceous ; front tarsi darkened, and the feet black ; palpi and tibial spurs pale ; costal veins in part testaceous, in part brown ; wings otherwise as in ♀.

♀♂. *Head* : face and clypeus throughout minutely punctate (degree 2) ; facial depressions nearer to apex of clypeus than to the eyes ; frons and vertex with exceedingly minute punctation (degree 1) ; posterior ocelli about equidistant from each other and the eyes ; flagellum of ♀ shorter than combined length of thorax and abdomen, about equal to length of thorax together with twice the length of the head, of ♂ about equal to combined length of thorax and abdomen together with three times the length of the head, equal to or rather shorter than three times the length of the thorax. *Thorax* : mesonotum throughout with closely placed, commonly indefinite punctation (degree 3), which almost gives the effect of minute rugosity, narrowly across extreme apex entirely smooth ; disc of scutellum with closely placed, indefinite punctation throughout (degree 3) ; propodeon more strongly sculptured in ♀ than in ♂, with a median longitudinal carina and transverse basal carinae that are commonly quite strongly marked but which are as commonly obsolete or even apparently wanting, the propodeon more or less smooth basally to the transverse basal carinae, otherwise reticulately rugose, this reticulation broader in the apical angles, or the apical angles even smooth. *Wings* : metacarp equal in length to stigma. *Legs* : hind coxae basally above with a large area strongly punctate (degrees 3 and 4), at apex above longitudinally striate, otherwise above and on outer faces minutely punctate ; hind tibial spurs equal in length, half the length of the basal segment of the hind tarsus. *Abdomen* (figs. 1, 2) ; 1st tergite basally excavate,

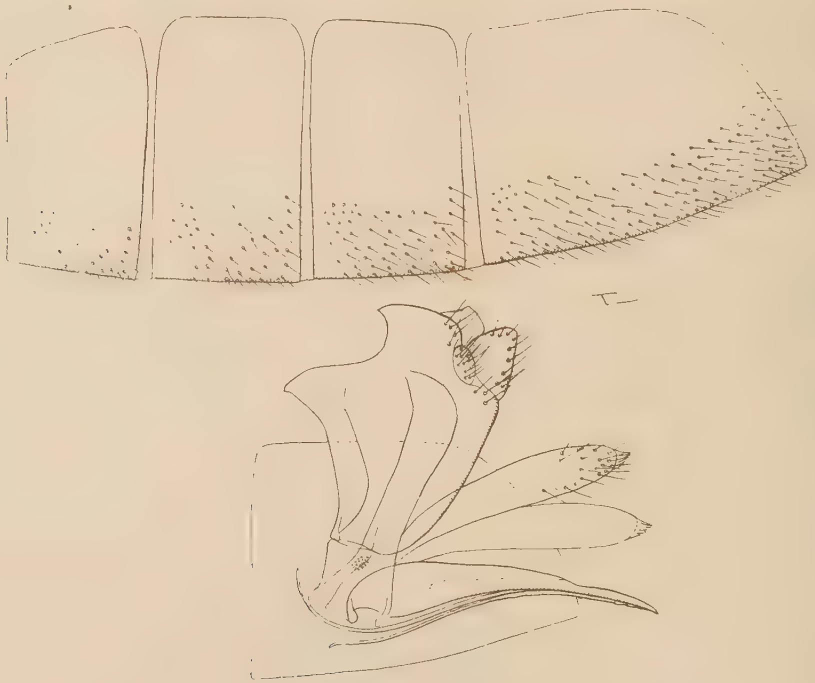

Fig. 2. *Apanteles praepotens*, Hal., apical ventrites and, below, genitalia, side view, ♀ (×80).

apically turned over, throughout apical half and to some extent along sides of basal half rugoso-punctate ; 2nd tergite rugose ; 3rd tergite smooth across base and apex and in a median basal triangle (these areas very variable in extent), but often with some very indefinite sculpture basally, otherwise minutely punctate ; succeeding tergites minutely punctate ; ventrites of ♀ without median longitudinal suture ; ovipositor sheaths shorter than the basal segment, about equal to or just shorter than combined length of 2nd and 3rd segments, the ovipositor just longer than the basal segment, of the hind tarsus ; hypopygium of ♀ truncate.

Length, 2·75–3·25 mm.

Redescribed from the following material :—MANCHESTER MUSEUM : Burnt Wood, Staffs., 1 ♀, em. 15.vi.1933, 11 ♀♀, 11 ♂♂, em. 16.vi.1933, Arnfield, Cheshire, 1 ♀, em. 19.vi.1933, 1 ♂, em. 23.vi.1933, Broadbottom, Cheshire, 1 ♀, em. 21.vi.1933 (*H. Britten*). IMPERIAL FORESTRY INSTITUTE : Parkend, Glos., 2 cards of 2 (each 1 ♀, 1 ♂), 9.vi.1933 (*J. M. B. Brown*). K. G. BLAIR'S COLLECTION : Brentwood, 2 ♀♀, 4 ♂♂, 10.vi.1933, det. as ? *salebrosus*, Marsh. D. S. WILKINSON'S COLLECTION : England, Brentwood, Essex, 80 ♀♀, 72 ♂♂, coll. 7.vi.1939, em. 28.vi.1939 (*R. L. E. Ford*).

Further material examined :—NATIONAL MUSEUM OF IRELAND, DUBLIN : Haliday Collection, 2 ♀♀ (one the *type*), no. 66. A. C. W. WAGNER'S COLLECTION : Germany, Buchwedel, 3 ♀♀, no. 46, 8.vi.1906, Bergedorf, 3 ♀♀, 1 ♂, no 49, 17.vi.1906.

Type in the National Museum of Ireland, Dublin.

Host. Haliday's original description of his *praepotens* is without host record. Of the material from which I have redescribed the species, or which I have seen, Britten's specimens are recorded by him to have been bred from the Tortricid *Tortrix viridana*, L., and Brown's fours specimens from the Geometrid *Hibernia*, now *Erannis*, *defoliaria*, Clerck, on this latter host the *Apanteles* being noted as an abundant parasite ; and Ford's long series was bred as an abundant, solitary parasite of fully grown larvae of the Geometrid *Operophtera brumata*, L., on oak. Blair's material from Brentwood is without host record, but, since the parasite pupated on stems of grass beneath oaks in exactly the same manner as Ford's material, which is also from Brentwood, the inference is that the host was *O. brumata* ; and I am informed by Dr. Blair that the oaks were heavily infested with *Tortrix viridana*, and that *O. brumata* was also plentiful. Finally, Wagner's material from Bergedorf is also recorded from this latter host, and his material from Buchwedel from *Operophtera boreata*, Hübn., which is now known as *O. fagata*, Scharfenb.

It should be pointed out, however, that, despite the long series bred by Ford from *brumata* and by Brown from *defoliaria*, *Apanteles praepotens* is not easily obtained from these hosts. *O. brumata* and *E. defoliaria* have been bred by Ford in very large numbers for several years from widely separated localities, without result.

There are only a few references to *A. praepotens* in literature. Lyle (1916, Entom., **49**, pp. 186–187) records the species as a parasite of the Geometrids *Eupithecia expallidata*, Doubl., and *E. nanata*, Hübn. ; but a dozen examples of the " considerable number " referred to by him as having been bred by Major Robertson from *expallidata*, and some three or four others from *nanata*, all of which are quite obviously the material upon which he based his records, are before me as I write, and are unquestionably not referable to *praepotens*. Fahringer (1935, Op. bracon., pp. 129–130), without referring to the source of his information, as is his reprehensible practice in this work, in addition to the two species of *Eupithecia* that I have now shown were incorrectly recorded by Lyle, and for which two species he incorrectly uses the generic name *Tephroclystia*, records as hosts of *praepotens* the Lymantriids *Euproctis chrysorrhoea*, L., *Porthesia similis*, Fues., and *Lymantria dispar*, L., and the Agrotid *Taeniocampa*, now *Orthosia*, *miniosa*, Schiff., none of which records I am prepared to accept.

Cocoons solitary, lemon-yellow when fresh, later fading to pale or even very pale lemon-yellow. When *O. brumata* is the host, the *Apanteles* cocoons are to be found on stems of grass under the oaks.

Commentary. Haliday originally described his *praepotens* from an unstated number of females only, from his own collection, since he mentioned no other, as was his habit when describing material from some collection other than his own, and from material that apparently had not been bred, since he gave neither host nor habitat. In the remains of the Haliday collection in the Dublin Museum is a female labelled, in the minute hand-writing usual for this collection, "*praepotens*" and "66," and another female labelled simply "66," which agree perfectly with Haliday's original description. I propose to accept this first female as the type, which almost undoubtedly it is; and I am so labelling it. It agrees perfectly and in the minutest detail with all the other material before me from which I have redescribed the species.

Marshall (1885, Trans. Ent. Soc. London, **1885,** p. 177) did not know the species, and incorrectly synonymised it with *brevicornis*, Wesm., under *sericeus*, Nees. Reinhard (1881, Deut, ent. Zeit., **25,** p. 34), also, synonymised it, with a query, with *brevicornis*, Wesm., which is, however, abundantly distinct.

In my key (1932, Trans. Ent. Soc. London, **80,** and as subsequently emended from time to time), until I have been able to put the key for this section of the genus on a sounder basis, this species must be placed with *glomeratus*, L., and *paludicolae*, Cam., to which in couplet 79 it easily runs under the present unsatisfactory arrangement. Couplet 79 must be altered, therefore, as follows :—

79. Second tergite with its sulci noticeably more deeply impressed at base ; 3rd tergite with large areas entirely smooth ; cocoons in a gregarious mass......... *glomeratus*, L.

Tergites not so describable ; cocoons solitary..79a

79a. Hind coxae basally above with a large area strongly punctate (degrees 3 and 4) ; cocoons lemon-yellow, or pale lemon-yellow ; Europe...........*praepotens*, Hal.

Hind coxae without such an area basally above ; cocoons white ; Ceylon, Sudan .... *paludicolae*, Cam.

NOTE ON TWO EGG-PARASITES OF *ANTESTIA LINEATICOLLIS*, STÅL.

By Ch. Ferrière, D.Sc.,
Imperial Institute of Entomology.

During his researches on the insect pests of coffee and their parasites in Kenya Colony, Mr. R. H. LePelley has bred two interesting Chalcidoidea from the eggs of the coffee-bug, *Antestia lineaticollis*, Stål.

One of these breedings, in which he has been able to study for the first time males and females together, solves a question which had been puzzling us for many years. The other has brought to light a new species belonging to a genus which had been found previously only in Australia, the Philippine Islands and India.

Anastatus antestiae, Ferr.

Anastatus bifasciatus, Fonsc., var. *antestiae*, Ferrière, Bull. Ent. Res., **21,** 1930, p. 34, fig.

Anastatus brevipennis, Ferrière, Stylops, **4,** 1935, p. 149, fig. (new syn.).

In 1925, the Imperial Institute of Entomology received from Mr. G. L. R. Hancock, in Uganda, a certain number of males of an *Anastatus* of which the females were unknown. As almost at the same time females of an *Anastatus* agreeing in most respect with the palearctic *A. bifasciatus*, Fonsc., were received from Uganda, it was the opinion of the late Dr. Waterston at that time and of myself later that these males, differing little from the males of *A. bifasciatus*, were only varieties of that species. They were described accordingly.

Since then, specimens were received from time to time from Kenya and Uganda, all bred from the eggs of *Antestia*, and always only males.

In 1935, when studying some exotic Eupelmidae, we found a small short-winged species, bred in Uganda by Mr. H. Hargreaves from the eggs of an unknown bug, which was described as *Anastatus brevipennis*. Only females were known.

Mr. Le Pelley succeeded at last in breeding males and females together of the *Antestia* parasite and sent us series of them. It was thus possible to recognise that the short-winged, brownish females and the small, black, normally winged males, although showing a great sexual difference, belonged to the same species, which must be called *Anastatus antestiae*, Ferr.

At the same time as *antestiae*, we described two other forms of males, differing only by the structure of the antennae, and bred from *Antestia* eggs together with the normal form. As no other forms of females are known in these eggs, these males must still be considered as varieties and should be called *A. antestiae* var. *longiclava*, Ferr., and *A. antestiae* var. *hancocki*, Ferr. Drawings of the three forms of antennae have been given in my first paper.

Acroclisoides africanus, sp. nov. (fig. 1).

♀♂. Head and thorax dark green, the back of the head blackish ; abdomen aeneous, with blue and violaceous reflections, the second segment more or less brownish. Antennae light brown, scape and pedicel yellow. Legs entirely light yellow, the base of the coxae and the hind femora somewhat darkened in the larger specimen. Tegulae and mandibles, except the brown teeth, also yellowish.

Head large, transverse, broader than the thorax ; eyes small, short oval ; ocelli in a low triangle, the lateral nearer to each other than to the eye-margin ; occiput margined. Seen from in front the head is broader than high, the cheeks about as long as an eye, converging strongly below ; clypeus not distinctly separated from the face, with striae radiating from the mouth ; face finely reticulated higher up ; mandibles big and strong, with long teeth. Antennae inserted high on the face, not far from the ocelli, and near each other. Scape narrow, reaching much above the ocelli, pedicel rounded, two small annelli, the first funicle joints about twice as long as broad, the last two joints slightly shorter, club narrow, a little longer than the two preceding joints together.

Thorax closely reticulated, short, not much longer than broad. Pronotum short, not margined anteriorly ; mesonotum much broader than long, with narrow but complete parapsidal furrows ; scutellum as long as broad, as strongly reticulated as the mesonotum, but smooth at tip, behind a very faint transverse furrow ; propodeon rather short, punctate in the middle, without median carina, but with broad lateral furrows. Wings large, reaching far beyond the end of the abdomen ; marginal vein thicker and slightly shorter than the postmarginal vein ; stigmal vein narrow, shorter than the marginal vein. Legs rather thin ; hind tibiae with only one spur.

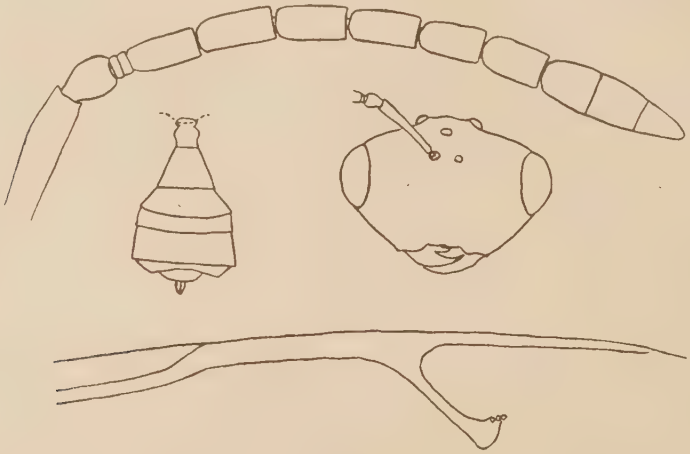

Fig. 1. *Acroclisoides africanus*, sp. n. ♀ ; antenna, abdomen, head and wing nervature. (Head and abdomen are drawn to the same scale.)

Abdomen triangular, smooth, narrower and shorter than the thorax, even shorter than the breadth of the head ; petiole short and narrow, slightly longer than broad ; second segment narrow at base, broadening behind ; third to fifth segments broad, the fifth the broadest ; last segments more or less hidden. Ovipositor slightly protruding.

Length, ♀♂ 1–1·5 mm.

Kenya Colony : Kiambu, 3 ♀ 1 ♂, 15.ii.1933 (*R. H. LePelley*), " ex eggs of *Antestia lineaticollis*." Belgian Congo : Mulungu, 1 ♀, 1937 (*P. Lefèvre*), " collected on coffee-plant."

The two Asiatic species are also parasitic in the eggs of Pentatomidae. *A. luzonensis*, Gahan (Philipp. J. Sci., xvii.1920, p. 345) was bred from the eggs of *Tectocoris lineola*, F., and *A. indicus*, Ferr. (Bull. Ent. Res., **22,** 1931, p. 279) from the eggs of a Pentatomid on a teak leaf.

In my key to the five known species, *A. africanus* runs near *A. indicus*, but this last species is larger, has a thicker marginal vein, a larger and more rounded knob of the stigmal vein, a longer second abdominal segment and a distinct median carina on the propodeon.

INVESTIGATIONS ON THE COTTON BOLLWORM, *HELIOTHIS ARMIGERA*, HÜBN.

PART III. RELATIONSHIPS BETWEEN OVIPOSITION AND THE FLOWERING CURVES OF FOOD-PLANTS.*

By F. S. Parsons, B.Sc.Agr., F.R.E.S.

Introduction.

In pursuit of information, during 1930–31, on the control value of egg parasites, it was found that the bollworm moth did not lay eggs in quantity on cotton for any lengthy period in the long growing life of this plant ; it appeared that the moths from time to time transferred their laying activities to other crops. Examination of the incidence of egg-deposition on other crops indicated that the egg-laying moths also inhabited or visited them only for rather short periods ; and it was observed for many of them that there was no return visitation. The existence of specially attractive stages of plant growth, and of certain species of plants having a greater attraction for the egg-laying moths, was suggested.

Except as regards maize, the voluminous literature, prior to 1932, on the American bollworm does not contain statements specifically relating oviposition to the growth stages of food-plants, although in retrospect relationships are discernible in some of the data provided. Many workers have reported, primarily from America, that the maize plant when in silk is most attractive to the moth for egg-laying. It is clear from the observations in the United States of Quaintance & Brues[21], McColloch[11] and Ditman & Cory[6], among others, that, although eggs are laid to some extent on maize before and after silking, the peak of oviposition falls within the period of silk production. Illustrations by Ditman & Cory of the courses of oviposition and silking on serial plantings of maize in Maryland evince a close relationship ; relatively few eggs were laid before and after the period of production of the silks or pistillate flowers.

Maize provides an instance of an insect-plant association of a particular character and, on the strength of American experience, its use, variously planted, as a bollworm trap-crop has been advocated in most cotton-growing countries. On the assumption that the silking stage is most attractive to the moth, maize was employed for trapping purposes by European cotton-growers in southern Africa, but the practice was abandoned as observers found fewer eggs on maize (numbers of eggs on silks being their criterion) than on adjacent cotton plants. Eventually a maize-bollworm relationship differing from that reported by others was found to apply in southern Africa, and the trapping value of maize was reasserted by Parsons & Ullyett.[13] The instance of maize receives further prominence in the present paper.

Bollworm-food-plant associations were made the subject of early and particular inquiry at Barberton, and a coincidence of egg-deposition and florescence was observed for a number of field and orchard crops. The relationship was reported first in 1932.[14]

In succeeding years surveys were made in the cotton-growing areas of the Transvaal, Natal and Swaziland, and close observations on the course of oviposition and the associated growth-fruiting condition of the crop were repeated extensively for all the prominent cultivated and wild food-plants of the bollworm. With certain exceptions to be noted later, it was determined for these territories that the egg-laying and flowering periods in fact are associated very closely, and that for all practical purposes egg-laying may be considered as confined to the flowering period. Instances of the relationship were illustrated by Parsons & Ullyett[13] in 1934 and its utility in studies of the relative attraction of different crops and of the times they became and remain attractive, as dependent upon planting dates and flowering habits, was indicated. On the same occasion attention was drawn to prospects of reducing the menace of bollworm to cotton by judicious plantings of alternative food-plants. Measures were taken accordingly and their nature and the success attending their application have been indicated in Progress Reports from this Station[15] and, more recently, in underlying connections with the data in Parts I and II of this series.

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* Contribution from the Cotton Insect Pest Control Section of the Cotton Experiment Station, Barberton, Transvaal, Union of South Africa,

Apart from the immediate mitigation of bollworm infestations of cotton, as obtained by the exploitation of the oviposition-flowering relation, a basis was provided for practically the whole of our investigations of boll-worm behaviour. By its means a rhythm in the annual incidence has been detected[16] and assistance given in studies of the status of parasitic agents for artificial and natural control.[17, 18] But, heretofore, the relationships between oviposition and flowering curves have been communicated in part only. Omissions are remedied in the present paper and the subject is discussed in its several bearings on problems of control. The occasion also serves as a convenient prelude to the presentation of results from other investigations, in all of which these relations are of intrinsic importance.

Methods and Procedure.

The methods used for recording eggs laid and plant development have been described elsewhere, [13, 10] but some repetition here is needful.

Prior to 1934 Clapham's method[5] and randomized block methods were utilized in field work of an experimental nature. These methods were developed for plant experimentation and sufficed for the plant portion of the observations. But the form of the distribution of *Heliothis* eggs on crops was not then known and the validity of the sampling technique in this respect was in question. The difficulties were overcome in 1934 by the author's colleague, Mr. Joseph Marshall, who found[10] that the distribution of the egg population on grouped sample units conforms to the normal curve, and he devised the sampling methods since in use.

Marshall has shown[10] that there is greater variation of egg numbers between than within rows of plants. He determined that this is due to differences in numbers of plant per row. The effect of differences in plant number can be eliminated for individual counts through analysis of covariance, but the correlation of stand (plant numbers) and egg population may disappear in successive records under the influence of secondary effects of stand, such as differential rates and extents of vegetative and reproductive growth. Previous to Marshall's investigation of egg distribution, the author had observed that the egg population was consistently greater in the better grown and more freely flowering portions of sundry crops ; distinctions could be drawn in this respect between single plants. In the case for cotton the author found a correlation of $r=0{\cdot}370$, with P less than $0{\cdot}01$, between size of plant and numbers of eggs laid. Marshall, in the work quoted, obtained a similar correlation for maize, and his further analysis indicated that the same portions of the crop retain their relative attraction to the bollworm moth. These disclosures conveyed the need for a wide scatter of the sampling units.

The sampling method used since 1934 allows of a scatter in forward and reverse echelons covering, usually, 50 rows per traverse. The number of traverses and the nature of the individual samples taken depends on the shape and size of field, type of crop, inter- and intra-row distances, and the requirements for efficiency pertinent to the case, as taught by experience.

The methods employed before 1934 in *experimental* work were based on the assumption of a normal distribution and contained all the features of breadthwise sampling. The data, therefore, are admissible and they have been drawn on liberally in the expositions here presented.

Poor-growing patches occur in most commercial crop lands and over portions of experimental fields. In recent years the backward plants produced within them have not been sampled in view of the rarity of egg-deposition on them.

Plant Records.

Planting dates were recorded. Weekly or twice-weekly notes were made on plant development and the general condition of the crops.

Depending on the nature of the inflorescence, the progress of flowering and fruiting was recorded by counts, measurements and notes daily, twice-weekly or weekly.

In different seasons, growth increments, height and size of plant body, were measured for cotton, maize, sorghum and bean (*Phaseolus vulgaris*). The plant means in variously grown sections of crop were found and examples taken for planimeter determinations of surface areas of leaf and stem. Impressions that the moths in egg-laying favour the best-grown portions were verified and the evidence of correlations between high egg counts and large, healthy plants was obtained from these data.

Egg Records.

Methods were evolved in the first instance for estimation of the status of egg parasitism. Knowledge in general of the fate of eggs was required and the eggs laid nightly were marked *in situ*. Later, as the egg is an evident and immobile indicator, it was considered that the particulars of egg-laying would prove most informative in preliminary studies of bollworm-food-plant relations, and the daily marking technique was applied in that connection. But the needful time and labour prohibited its use as widely as desired, and recourse was had to egg counts only.

The mean incubation period of the egg in the warm season lies between 72 and 96 hours, and a twice-weekly count was found to give adequate data for appreciating the duration of oviposition and the shape of the oviposition curve. Some recounting is inevitable, more of it occurring as incubation periods lengthen with falls in temperature, but the course of events depicted by marking or counting only was found to agree well enough for the purposes.

The egg-counting method became a routine measure here, and for nearly 10 years the information obtained through it has supplied continuous indices of bollworm incidence.[16]

The areas of crop under record in each situation were measured approximately and mapped for purposes of estimating eggs-per-crop-area, relative attraction of crops in terms of acreage ratios and the distance and direction of the inter-crop movement of moths. Information on the last-mentioned points was obtained from plotting target diagrams of the egg counts on plant samples that were taken specifically in strips across the fields ; the information is referred to in the section on Variations.

Native Africans have been employed in the taking of the routine records. They display an aptitude for the work and are comparatively impervious to its tedium. Without their assistance, generally honestly given, it would have been impossible to amass the quantity of comprehensive information sought. Upwards of 50 native enumerators have been engaged constantly in recording under European supervision.

Evidence of Relationships.

It should be understood that the relationships to be discussed concern oviposition on flowering plants, not oviposition on the flowers of plants. The moths deposit their eggs on many parts of a plant ; as a rule, relatively very few are laid on the flowers. The following records of egg distribution on cotton and maize are given as examples :—

TABLE I.

Distribution of Eggs on Cotton and Maize.

Cotton.	No. of eggs.	Maize.	No. of eggs.
Leaf surfaces, upper	536	Stalk	629
,, ,, lower	86	Leaf surfaces, upper ...	305
Bracts	364	,, ,, lower ...	77
Leaf petioles	122	Tassel	224
Bud and flower peduncles ...	116	Silks	31
Upper branches	109	Cobs	22
Upper main stalks	13		
Boll peduncles	29		
Leaf buds	17		
Growing tips	8		
Flowers	6		
Young bolls	4		
	1,410		1,288

In view of some differences in their oviposition-flowering relationships, data are submitted separately for short and long-flowering species of crop.

The information which concerns the bounds of the oviposition period was regarded as authentic following observations on 200 various crops at Barberton between 1930 and 1933 and, as confirmations were obtained here and farther afield, examinations for eggs during the early vegetative and late fruiting phases were discontinued, except as regards newly introduced or discovered food-plants. Where attention is drawn in the following to the time oviposition commenced and terminated, egg-laying *in quantity* is referred to.

The examples given in the first instances represent what are regarded as the normal relationships ; variations and exceptions are discussed later.

Scales of oviposition and flowering are not included in the illustrations of fit between oviposition and flowering curves, because the rates of flowering and weights of oviposition per species vary greatly and adherence to a common scale or use of different scales would confuse rather than assist interpretation.

Short-Flowering Species.

In fig. 1 are given examples of oviposition and flowering relations observed for peas, soya bean, tepary bean (*Phaseolus acutifolius*) and the Canadian Wonder, a commonly-grown variety of field bean. The three examples for peas and four field beans are drawn from the most detailed instances of examination. They are representative of the ordinarily slight variations as indicated by records from similar or less detailed examinations that have been carried out over 9 years in 44 pea and 50 bean crops.

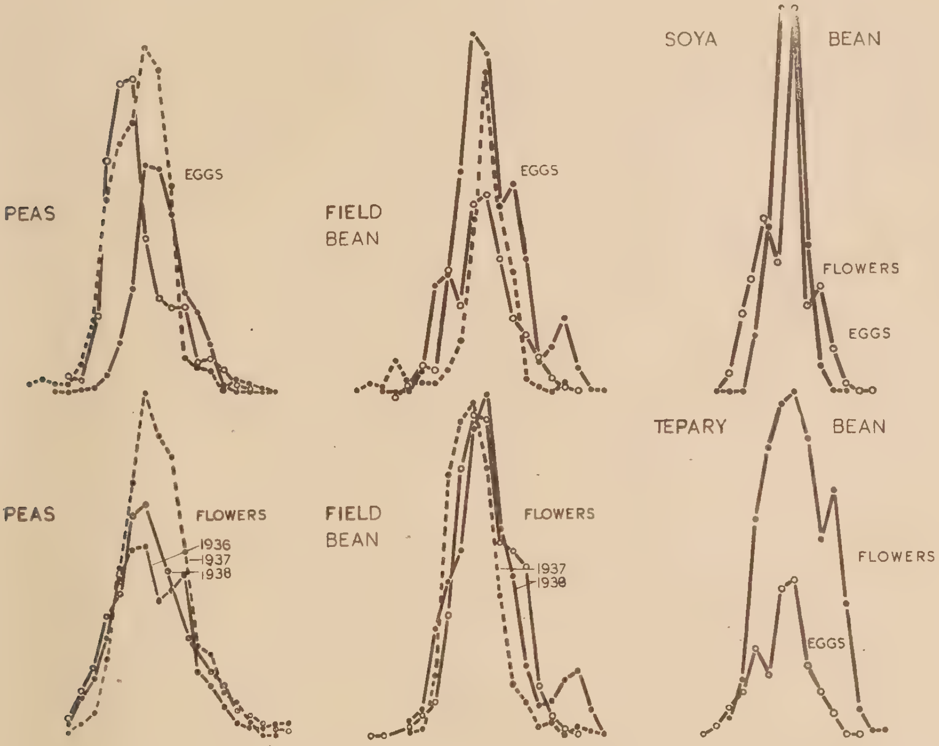

Fig. 1. Oviposition on peas and three species of beans in relation to flowering.

The tepary and soya beans observed grew in proximity to maize and other crops more attractive to *Heliothis*, and eggs were seldom found on them. Parallel egg and flower counts were secured only in the single instances portrayed in the figure. But similar relations are evident from egg counts, the shape of oviposition curves and accompanying notes on the condition of budding and flowering in records on 5 other tepary and 3 other soya bean crops, where notable oviposition occurred.

Flower counts on peas and the three types of bean include advanced buds and semi-open flowers, as many of them fertilize before opening.

It is evident from the data for the four species concerned in fig. 1 that, firstly, comparatively few eggs were laid until florescence was imminent (young buds had appeared before eggs were found) and that egg-laying declined with flowering to end with it. Secondly, the curves of oviposition and flowering are of the same shape and their peaks practically coincide. It is of interest to note that Barber recently reported[1] observations of concentrated laying by *Heliothis* on freely-flowering soya beans (and flax), while neighbouring fields of them, where flowering had declined, were ignored by the egg-laying moths.

Two East Indian strains of the Hyacinth or Bonavist bean (*Dolichos lablab*) may be considered with the above group. The strains of *Dolichos* were introduced from India to test their conformity or otherwise with the oviposition-flowering relations in comparison with a strain procured from Rhodesia which proves to be an exception (*cf.* section on Exceptions). Since introduction they have been studied for two seasons, in both of which the oviposition and flowering curves were aligned closely.

Fig. 2 illustrates oviposition as it occurs in conjunction with the exsertion and development of sorghum panicles and spikelets and of maize tassels and silks.

The plant development data for sorghum are from a non-suckering strain of the black-hulled kaffir type and exhibit the usual degrees of variation found in commercial crops. Heading and flowering on other types of sorghum with suppressed suckering follow a very similar course.

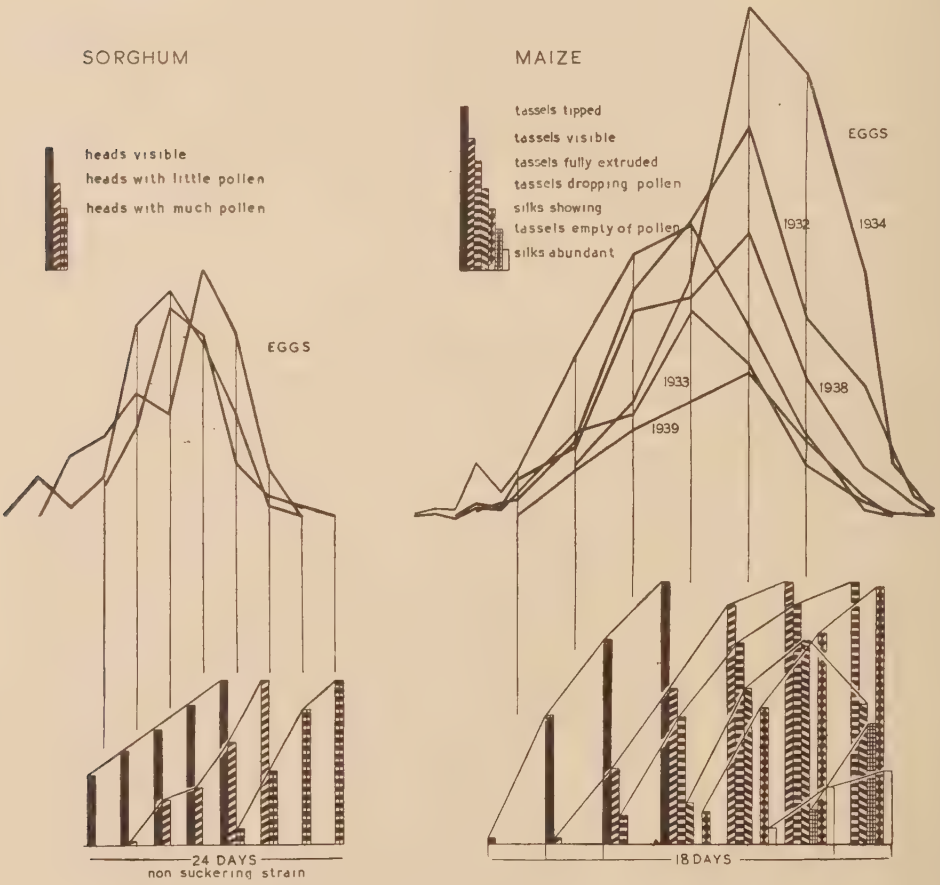

Fig. 2. Oviposition on sorghum and maize in relation to florescence.

When suckering occurs there is repetition and overlapping of the heading and flowering events. The crop then assumes a long flowering character, and oviposition may or may not continue according to points raised in the section on long-flowering species.

Nearly 300 crops of different varieties of maize have been observed since 1932. At one time a flint variety was of chief importance. The very close agreement between the times of occurrence of oviposition and flowering (tasselling) on this variety was figured in an earlier paper.[13] Latterly, strains of Hickory King have been grown to the greatest extent, and the diagram in fig. 2 illustrates the course of florescence from the extrusion of tassels to the production of green silks in commercial fields of this variety, but a very similar train in proportion and time of the flowering events obtains for a number of other varieties that have been observed in experiments at Barberton.

The graphs of oviposition inserted above the sorghum and maize diagrams are indicative of the range of normal relations. High laying on both species occurs over the brief period of panicle or tassel extrusion. Contrary to American experience, relatively few eggs are laid here on maize during its full silking phase or, in fact, before or after tasselling.

In relating the peaks of laying from separate records to the one diagram per crop, difficulties may be expected owing to variations in growth within individual crops. Actually, and having regard for the fact that points on the graphs fall at intervals of only 3 to 4 days, there is, as seen from fig. 2, close similarity in the timing and form of the curves. One explanation of this is that laying tends to follow flowering behaviour on the more advanced portions of sorghum and maize crops; even in the most uniform-appearing crops there is a considerable lag in flowering.

Maximum oviposition occurs on sorghum and maize about the time the majority of heads or tassels are well extruded and pollination in part has commenced.

Oats and Barley.

Relations similar to the above have been recorded in these crops. Notable egg-laying was associated with the stage of green ear formation and reached a maximum about midway in the flowering life. Eggs were found to be deposited almost exclusively on the oat panicles or barley spikes. There have been few opportunities for observation, however, and whether the relationships are applicable generally to these crops remains to be established.

Sunflower.

The available crops of sunflower were few and of small acreages grown for experimental purposes. Of 11 crops examined, appreciable oviposition occurred only in the three instances of which information is presented in Table II.

Exposition of the course of budding and flowering of sunflower plants presents unusual difficulties owing to variations within the crop of the time and rate of development of the determinate flower-heads, and descriptive notes, as rendered in the Table, were relied upon in place of numerical classifications. But in the examples given, notes were taken by different observers and some doubt is felt as to whether the egg counts are tabulated appropriately. Allowing for some latitude in that respect, it is clear that the important egg-laying occurred within a period ranging from the appearance of advanced buds, some bearing exserted florets, to the fading of the florets as a whole.

TABLE II.

Oviposition on Sunflower (Helianthus annuus).

Condition of crop.	Recording occasions 3–4 day intervals.		Eggs found (48 plant sample)		
			Ex. 1.	Ex. 2.	Ex. 3.
Pre-budding	1st		0	0	0
	2nd		0	0	0
	3rd		0	0	0
	4th		0	0	0
	5th		0	0	0
	6th		0	0	0
Young buds present	7th		0	0	0
	8th		2	0	0
Young and developed buds	9th		0	0	0
	10th		6	0	1
Few young, mainly developed buds...	11th		12	0	0
Developed and well-advanced buds	12th		60	38	7
Advanced buds, florets erect on segment of corona of a few heads	13th		360	50	0
Mainly advanced buds but partly open flower-heads frequent	14th	34 days	300	150	10
Partly open flower-heads numerous	15th		260	180	27
Partly open flower-heads abundant, florets fully extruded in few instances	16th		315	170	82
Corona of florets complete in most instances, heads broadened	17th		240	175	98
Early-opened heads fully broadened and pollinating ...	18th		370	875	290
Majority of heads of full width and with pollinating zones	19th		290	470	316
Flower-heads fully developed, pollination abundant ...	20th		215	280	212
Fully developed heads general, pollination less, florets fading on early-opened heads	21st		230	228	250
Fresh flower-heads still numerous, pollination infrequent...	22nd		170	280	120
Progressive fading of florets	23rd		25	240	300
Few fresh flower parts	24th		0	130	123
No fresh flower parts	25th		0	36	60
Drying off	26th		0	0	0
	27th		0	0	0
	28th		0	0	0

TABLE III.

Distribution of Eggs on Tobacco Plants in different Stages of Development.

CROP I.	Pre-budding plants			Budding plants			Flowering plants			Budding and flowering plants		Topped plants		
Total eggs	Propn. of crop per cent.	Eggs laid	Propn. of total eggs per cent.	Propn. of crop per cent.	Eggs laid	Propn. of total eggs per cent.	Propn. of crop per cent.	Eggs laid	Propn. of total eggs per cent.	Propn. of crop per cent.	Propn. of total eggs per cent.	Propn. of crop per cent.	Eggs laid	Propn. of total eggs per cent.
360	100	360	100	—	—	—	—	—	—	—	—	—	—	—
375	100	375	100	—	—	—	—	—	—	—	—	—	—	—
240	100	240	100	—	—	—	—	—	—	—	—	—	—	—
140	94	128	91	6	12	9	—	—	—	—	—	—	—	—
200	84	135	67	16	65	33	—	—	—	—	—	—	—	—
1,175	43	155	13	50	620	53	7	400	34	57	87	—	—	—
2,865	8	16	00·6	16	670	23	76	2,179	76·4	82	99·4	—	—	—
1,440	—	—	—	4	28	2	75	1,395	96·8	79	98·8	21	17	1·2
100	—	—	—	—	—	—	—	—	—	—	—	100	100	100
10	—	—	—	—	—	—	—	—	—	—	—	100	10	100
CROP II														
0	100	—	—	—	—	—	—	—	—	—	—	—	—	—
0	99	—	—	1	—	—	—	—	—	—	—	—	—	—
20	97	—	—	3	20	100	—	—	—	—	—	—	—	—
80	95	56	73	3	8	10	2	14	17	5	27	—	—	—
530	83	249	47	5	43	8	12	238	45	17	53	—	—	—
510	83	429	84	1	25	5	2	57	11	3	16	14	—	—
580	71	192	34	7	128	22	8	151	26	15	48	14	110	18
690	46	186	27	9	62	9	16	365	53	25	62	29	77	11
1,930	37	212	11	6	347	18	3	752	61	9	79	54	193	10
1,260	30	479	38	9	176	14	7	730	42	16	56	54	75	6
870	21	348	40	6	192	22	2	295	34	8	56	71	35	4
130	—	—	—	20	38	29	9	92	71	29	100	71	—	—
100	—	—	—	8	14	14	2	83	83	10	97	90	3	3
200	—	—	—	—	—	—	—	—	—	—	—	100	200	(green portion of plants)
70	—	—	—	—	—	—	—	—	—	—	—	100	70	

Extracts from Records on ten other Crops.

Case No.	Pre-budding		Budding and flowering		Topped plants	
	Propn. of crop per cent.	Propn. of total eggs per cent.	Propn. of crop per cent.	Propn. of total eggs per cent.	Propn. of crop per cent.	Propn. of total eggs per cent.
1	92	56	8	44	—	—
2	74	48	16	52	—	—
3	70	25	8	50	22	25
4	75	12	13	88	12	—
5	59	39	16	45	25	16
6	25	11	55	99	30	—
7	12	3	79	97	16	—
8	22	1	12	89	66	10
9	64	19	24	71	12	10
10	55	32	11	48	32	20

Tobacco.

Tobacco lands are planted with seedlings from nursery beds. The seedlings in each transplanted lot vary as to age, size, development and health. As one to two or more weeks may elapse before a field is planted fully, the variations between plants are repeated and extended as each transplanted lot is set out. Flowering curves are unobtainable, as budding and flowering occur sporadically and usually the flower-heads are plucked wholesale and continuously to encourage leaf growth. In view of these circumstances the method of examination adopted for tobacco crops was to take a census weekly or bi-weekly of (1) young plants (all plants in the pre-budding stage), (2) budding, (3) flowering and (4) topped plants. Egg counts were made on samples of plants in each category.

The details of egg distribution on varying proportions of the plant classes are given for 12 crops in Table III. The data for Crop I are presented as a special instance, and the only one in our records, where a field had been planted in the one day with fairly equally-grown seedlings, a large proportion of which came into bud at the same time. Furthermore, topping was delayed greatly, so much so that half of the flowered plants bore green seed-capsules before topping occurred. The situation approximated closely to a uniform and normal development of tobacco plants and is comparable in the present connection with crops that are sown in the field. It may be seen from the Table that high egg-laying on Crop I was associated with the budding and flowering stages. Crop II is representative of the proportional distribution of eggs found throughout the development and following upon the ordinary methods here of handling European-grown tobacco plants. The point of chief interest in the data is the preponderance of eggs laid on the fleetingly low proportions of the plants that were in bud and flower. This is also apparent in the additional cases given below the Table, which have been extracted from the records on 10 other crops grown at various points in different seasons.

TABLE IV.

Records of Numbers of Eggs laid at Sample Points on 48 Washington Navel Trees—twice-weekly Counts.

Occasions	Plant Records (twice-weekly)	Ex. 1, 1933	Ex. 2, 1934	Ex. 3, 1934	Ex. 4, 1936	Ex. 5, 1936	Ex. 6, 1934	Ex. 7, 1934	Ex. 8, 1934
1st	Pre-budding	0	0	0	—	—	(Weekly records, distant citrus estates)		
2nd		0	0	0	—	—			
3rd		0	2	0	—	—	—	—	0
4th		0	0	3	—	—	—	0	—
5th		4	3	1	—	—	0	—	24
6th	Young buds	9	12	0	0	0	—	125	—
7th	Young and mature buds ...	26	19	23	9	0	171	—	116
8th	Flowers intermittent	87	90	74	23	12	—	371	—
9th	Flowers abundant	173	216	770	46	32	1,597	831	904
10th	Flowers at maximum ...	271	538	745	101	176	—	—	—
11th	Flowers abundant*	54	100	345	86	139	691	172	254
12th	Flowers reduced	34	66	—	48	19	—	—	—
13th	Flowers few	15	0	30	27	12	15	10	14
14th	Flowers rare	5	0	0	10	0	—	—	—
15th	Flowers rare	2	0	0	0	0	0	0	0
16th	No flowers	2	0	—	—	—	—	—	—
17th		0	0	—	—	—	—	—	—
18th		0	0	—	—	—	—	—	—

*Flowers commencing to shed.

Other Species of Field Crop.

Relatively slender evidence that oviposition and flowering are related was also obtained in respect of mung beans (*Phaseolus mungo*), dwarf Lima bean (*Phaseolus lunatus*) and flax.

Citrus.

The time and course of oviposition on citrus were determined from records taken at five points at a convenient level round the periphery of trees. Each point consisted of the twigs and their bearing of foliage and blossom as produced on the outer, short arms of a subsidiary branch.

Most of our records on citrus were taken near Barberton, in the Transvaal, in the orchards (4 to 10 acres) of small growers where only the Washington Navel and Valencia varieties of orange and a little grape-fruit are set out. About one per cent. of the trees in the most uniform groves was sampled. Additional surveys were made in 1934 within a number of large estates in a distant neighbourhood devoted mainly to citrus-growing. On these occasions records were confined to small samples in selected groves of the Washington Navel and Valencia varieties.

The course and wealth of blossoming differ considerably from point to point per tree and the individual clusters of flowers contain variously developed parts. In consequence, budding, flowering and shedding behaviour over a grove as a whole was left to visual impressions, as described and classified in Table IV.

In the Table egg counts on Washington Navel trees are placed against the pertinent plant records for instances observed in 1933, 1934 and 1936. Weekly data collected on three of the estates visited in 1934 are included. In these eight examples a particularly well-marked coincidence of oviposition and florescence is evident. Identical relationships were recorded for the Valencias, a later variety, but egg-laying on grape fruit trees was never sufficiently in evidence to permit of conclusions.

Jones, in 1936, made note of egg-laying by *Heliothis armigera* on several kinds of crop with particular reference to the stage plants were in when egg-laying commenced and ceased. He states[9] that in all cases the period of oviposition coincided with the flowering stage, thus confirming the earlier conclusion in similar terms of Parsons & Ullyett.[13] Jones also observed the course of oviposition in a number of groves of Mediterranean sweet and Valencia late orange trees which blossomed in sequence, and it is appropriate to repeat here his observation that the laying occurred successively in the groves according to the sequence of blossoming. Jones emphasises the importance of the relationship in founding methods of control in citrus orchards.

Wild Food-plants.

Unfortunately for this study most of the species with short-flowering habits grow intermingled in all stages of growth ; the eggs are scattered as attraction of the moth varies, and the situation is too complicated for observation of their individual relationships. Reference may be made only to information secured in comparatively pure stands of 6 species, viz., *Abutilon indicum*, *A. soneratianum*, *Amaranthus thunbergii*, *Nicandra physaloides*, *Physalis angulata*, and *Solanum nigrum*. The courses of oviposition and flowering were synchronous.

The 21 species referred to exhaust the list of short-flowering crop or weed plants on which we have found commonly a close agreement of the oviposition and flowering periods.

It is expedient to state here that the relationships dwelt upon rarely appertain to single plants, even the larger, more freely-flowering individuals which the moths favour in egg-laying, but rather to the crop as a whole, or, if growth is irregular, to the better-grown portions. Furthermore they are rarely apparent except in data procured with sufficient frequency in adequately sampled areas. They are most sharply defined when the egg-laying is heavy and omissions in counting are less influential.

Using such methods in some of the crops mentioned in this and the succeeding section, Jones,[9] Peat[20] and Bebbington & Allan[3], working in the Rhodesias, have confirmed or supported the time relationship, and its existence has been accepted and utilized by Bedford & Cowland in measures for the control of American bollworm in the Sudan.[4] Sloan in Queensland has recognized[22] that maize is most attractive when in tassel. Possibly then (and recalling Barber's observations[1]) the main points concerned—coincidence of the bounds and peaks of the oviposition and flowering curves on short-flowering crops—are applicable widely and, in view of their obvious value in furthering attempts at bollworm control, it would appear that the subject merits the further attention of workers in other countries where *Heliothis* is troublesome. The statements apply with equal force to long-flowering species, though in their case the relations are not as clearly defined, for reasons given presently.

Long-Flowering Species.

Except as noted under Variations and Exceptions, the alignment of the courses of oviposition and flowering on short-flowering crops is exhibited over any period that falls under the curve of a moth flight. But, depending on the season of growth and the length of the corresponding moth flight, oviposition on a long-flowering crop may decline while flowering is still in progress, or there may be two or more waves of oviposition according to the number of moth flights spanned by the flowering period. Interpretation of the course of oviposition in these instances requires, therefore, a knowledge of the train of moth flights. Another consideration is that the moths comprising one or other of the flights may be attracted to a greater or less degree to more favoured species, with resulting irregular alterations in the scale of egg-laying during the course of laying on individual crops. Thus, although it is customary to find that oviposition on crops in this category commences in quantity with the appearance of flowers and does not persist beyond the flowering period, different courses of oviposition have been observed for individual species.

For convenience of reference, particulars of the moth flights and their division according to origin are summarized herewith from data contained in Part I :—

Flight I.—Moths from over-wintering pupae. The main flight extends from mid-July to mid-October. Over this period winter crops are produced under irrigation.

Flight II.—Moths bred in winter crops. Apart from some early winter-bred moths whose flight joins with Flight I, this flight occupies the period early October to mid-December.

Flight III.—Moths emerging from areas of wild food-plants, tobacco and maize in December and January.

Flights IV and V.—Moths bred in summer crops with periods of flight over February–March and April–May respectively. A partial 6th flight of small dimensions occurs in June.

The tails of the flights cross to some extent, but the successive periods of moth abundance are defined clearly, particularly as regards Flights I, II and III. Crops grown within the periods of their currency will be considered first.

Tomato (fig. 3.).

The greater portion of the tomato crop flowers from mid-August to early October. Although it is exposed, therefore, to the attentions of moths of Flight I for about a month prior to the appearance of flowers and to the moths of Flight II after flowering ceases, the oviposition and flowering curves synchronize. Examples from three years' records, labelled 1 in the figure, are given as representative of the relationships observed for this section of the crop.

Example 2 illustrates instances of especially early crops where flowering begins in July before moths of Flight I emerge and where the peak of flowering occurs before moths are numerous. Subsequent to the increase of moths a wave of egg-laying is experienced while flowering decreases, but the notable point is that egg-laying terminates with flowering in September, although moths of Flight I are present then in maximum numbers.

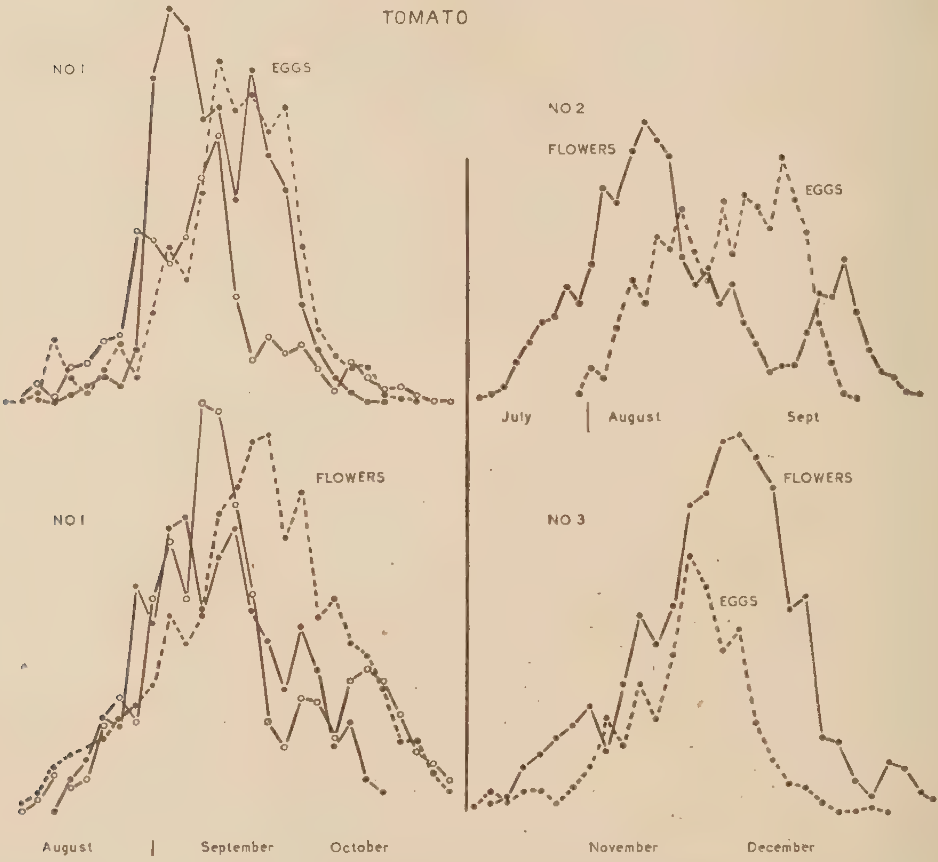

Fig. 3. Oviposition on tomato in relation to flowering.

Example 3 applies to relations recorded for late-planted tomatoes. These crops encounter hot weather, which has the effect of shortening their life and of generating a steep flowering curve. During their pre-flowering life they are available for oviposition by moths from portions of both Flights I and II, but the moths have refrained from laying on them prior to the appearance of flowers. In the case illustrated Flight II was ending and Flight III had barely begun before flowering declined ; hence at that time oviposition in general was relatively light. The moths in Flight III, however, do not oviposit on these crops in the many weeks of their post-flowering life.

Example 1 may be regarded as the normal relations and examples 2 and 3 as principal variations due to displacements in respect to the calendar time of moth flight. In arriving at these conclusions records from some 42 tomato crops have been consulted.

Cucumber (fig. 4).

The cucumber crops are in growth throughout the period spanned by Flights I and II, but again it was found that oviposition is limited practically to the flowering stage, and that, as seen from the figure, agreement exists between the forms of the oviposition and flowering curves. The crops recorded all flowered for the greater part within the period of Flight I or of Flight II, and opportunities to observe the course of egg-laying if, for instance, the tails of moth flights should cross midway in the flowering phase, have not arisen. Presumably (*cf.* marrow), a bi-modal curve of oviposition would be apparent.

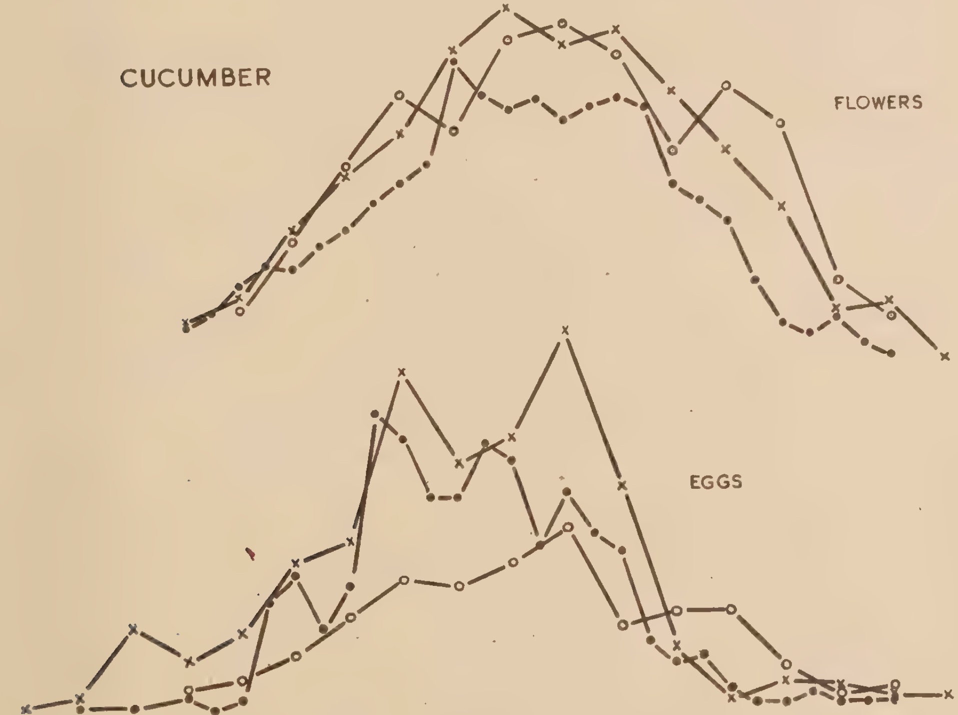

Fig. 4. Oviposition on cucumber in relation to flowering.

Marrow (fig. 5).

Additional instances of oviposition-flowering relations are evident in the data from marrow crops. The course of events on three of these crops with different planting dates is graphed in the figure. The graphs labelled 1 refer to the case for early planted crops which develop slowly in the coolest months of the year and have a protracted flowering life. They flower from about mid-August to early November and are subject, therefore, to egg deposition by moths in parts of both Flights I and II, with resulting major and minor waves of oviposition.

As the planting dates are advanced the flowering period is reduced, as a result, apparently, of higher temperatures. The graphs labelled 2 depict the courses of oviposition and flowering on a crop that entered the flowering stage in September. Flowering terminated before all but the earliest representatives of Flight II would be present, and only the one wave of oviposition was apparent. In this case the ending of Flight I and of the flowering curve coincided, and the fall of the oviposition curve could be taken as indicative of a fall in moth numbers. But it is clear that the oviposition and flowering curves over most of their lengths were related in the familiar manner.

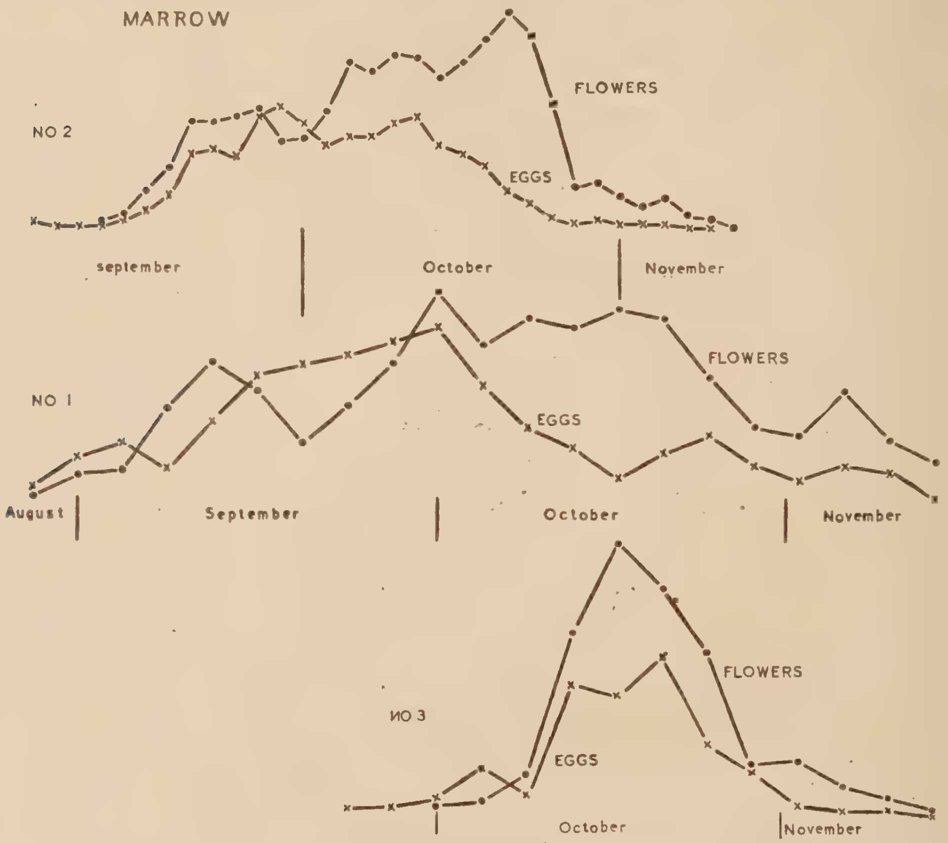

Fig. 5. Oviposition on marrow in relation to flowering.

Graphs 3 illustrate the relations recorded in late-planted marrow crops which have a comparatively short and steep flowering habit. Flowers appeared in October when Flight I was ending and Flight II had started. Laying terminated with the cessation of flowering about a month later, although moths of Flight II then would be most abundant. In these cases the conditions were the reverse of those described for example 2, significance now being attached to the conformity of the curves *after* the moth population had swollen.

Of 26 marrow crops observed, the great majority were of the No. 2 description to which a uni-modal oviposition curve and a protracted period of high laying during florescence apply.

Lucerne.

Observations were limited to one trial area. This was grown for fodder and cut periodically when in abundant flower. Opportunity was thus given to note the relative extents of egg-laying over successive periods on plants developing before and after florescence. Convincing evidence was obtained that the egg-laying moth is partial to this crop when it is in flower, and the particulars are reported in Table V. It will be noted that the egg population grew as flowering increased.

As regards the incidence of moths, those of Flight I were operative from the earliest growth to beyond the date of the second cutting, but they gave no real indication of their presence by way of egg deposition until flowers appeared. The last wave of laying was assigned to moths of Flight II and was judged to occur at the peak of the flight ; apparently, therefore, the earlier moths of this group were also not drawn to lay on the re-grown but non-flowering plants.

TABLE V.

Oviposition on Lucerne.

Condition of crop		Eggs found on 48 yard lengths
Pre-flowering		0
		1
		0
Budding	Flowering period	24
First flowers appear		180
Flowers general		590
Flowering freely		880
First cut for fodder		
Regrown well		7
Regrowth strong		26
Regrowth abundant		83
Regrowth luxuriant		132
Budding	Flowering period	197
Flowers appear again		326
Flowers general		377
Flowering freely		382
Flowering abundantly		749
Second cut for fodder		
Regrowth less rapid		7
Regrowth advanced		0
Regrowth abundant		20
Regrowth luxuriant		57
Budding	Flowering period	240
Flowers appear again		301
Flowers general		305
Flowering freely		437

Sunn Hemp.

Observation was kept on 19 crops of sunn hemp. It is grown in dense stands, and egg-laying, when spread over the extremely large plant population, must be very heavy to be apparent and to provide evidence of its course ; extra-large and additional sampling units are required. Occasions of heavy laying came under observation, but the crops were grown for green manure and were ploughed in when in flower, so that complete records were not procured. But it was established that egg-laying in quantity commences with the appearance of flowers, and in a few instances ploughing was delayed sufficiently to witness that egg-laying had risen and declined along with flowering.

Pumpkin and Cape Gooseberry.

Crops were examined from time to time. Oviposition was associated with their flowering phase and followed courses similar to those described for marrows.

Cotton (fig. 6).

Here cotton is planted after the earliest suitable rains, usually in October and November. Seedling plants are rarely evident before Flight I is over, but plants appearing in either October or November are exposed throughout their young growth stages to egg deposition, first by moths in Flight II only, which are soon reinforced and shortly replaced by moths in Flight III before flowers appear. Yet it is apparent from our records of the course of oviposition on 157 crops of cotton that the moths are not drawn to lay to any extent on cotton until advanced buds or open flowers have made their appearance, and that egg deposition declines to negligible proportions with the passing of the flowering period.

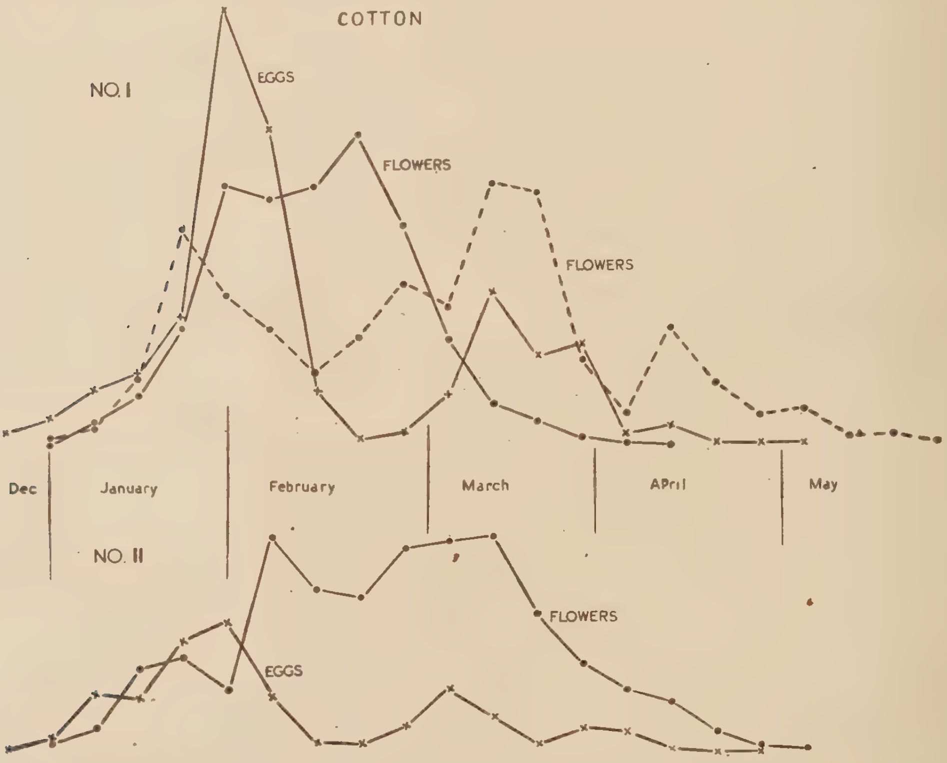

Fig. 6. Oviposition on cotton in relation to flowering.

Normally cotton here flowers over about 4½ months and is subject to oviposition from moths in part of Flight III and during the currency of Flights IV and V. As a rule the first wave of laying due to moths of Flight III is most evident. There is a simultaneous ascent of the oviposition and flowering curves, but the former falls away with diminution of Flight III well before the apex of flowering is reached. Moths in the tails of Flights III and IV then occasion a light laying, which generally is followed by a second period of increased laying during the main incidence of Flight IV. Events may also lead to the occurrence of a third peak of egg numbers due to moths in a portion of Flight V—the earlier portion, as the flight persists for some time after the termination of flowering on cotton.

In contrast to their choice of food on many other species of plant, all but the late instar larvae on cotton feed mainly on the buds and flowers. Thus, when the attack is at all heavy, flowering on cotton pursues an abnormal path. Example 1 in the figure (fig. 6) illustrates the instances of *heavy* first and second layings in relation to the flowering curve. Owing to the destruction of early buds by larvae from the first laying, the flowering is deranged from the normal uni-modal form (the unbroken line) to a bi-modal curve (the broken line) — the data are from observations in hand-infested and control plots of cotton. In effect heavy damage by bollworm during the first infestation leads to a wealth of flowering and enhanced attractiveness of the crop when moths of the second summer generation (Flight IV) are present in maximum numbers ; consequently the second egg-laying on cotton is liable to be unduly extensive.

In example 2 (fig. 6) oviposition of less magnitude is exhibited in relation to the appropriate record of flowering. The instance is representative of a frequent type of present-day relationship in the European areas studied where alternative food-plants of *Heliothis* now are grown in greater variety and in larger acreages in the neighbourhood of cotton and, in consequence, fewer eggs are laid on cotton. Under present conditions, and excepting attacks of epidemic proportions, the influence of the first generation larvae on flowering behaviour is, as indicated, relatively minor and questions of enhanced attraction during the period of Flight IV do not arise. In both examples a third, but light, rise in egg numbers is apparent.

Although the relationships quoted are frequently encountered, the course of oviposition on cotton is dependent to an unusual degree on the nature and volume of counter-attractant crops. Apart from the scale, the definition of the waves of laying varies widely and further discussion is relegated to the section on Variations in which the influence of counter-attraction is dwelt upon.

Groundnuts (fig. 7).

Egg-laying of importance on groundnuts is also confined to the flowering period. The examples supplied in the figure concern rain-grown crops which are laid on by

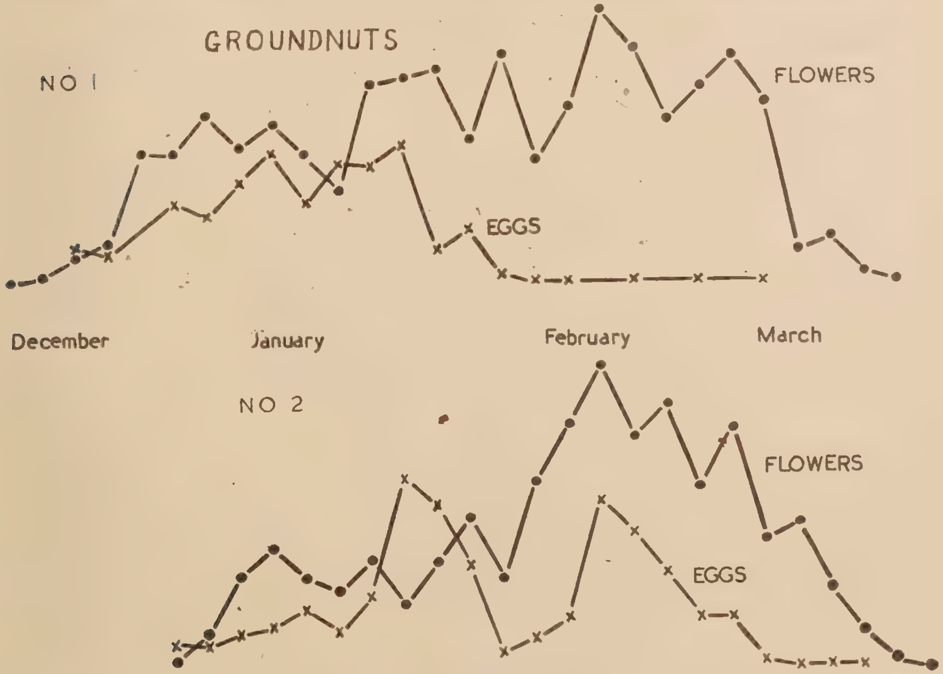

Fig. 7. Oviposition on groundnut in relation to flowering.

moths in Flights III and IV. Example 2, showing the two well-marked laying periods beneath the flowering curve, portrays the situation recorded in the majority of cases of semi-isolated groundnut crops.

Example 1 is of the nature of a variation but illustrates a relation fairly common to groundnuts when grown in a community of crops, *viz.*, the plants come into flower exceptionally early and when planted with the earliest rains flower well before other crops. They constitute, therefore, a rallying centre for the moths of Flight III and heavy first layings are experienced. The egg population then dwindles, often before Flight III is spent, and remains inappreciable owing to the greater attraction exerted by neighbouring crops of other species, notably maize and sorghum.

Variations of the Relationships.

The moths are deterred from laying or laying is reduced erratically during periods of rain, dust storms, high winds and low temperature. Ordinarily, variations in the scale of oviposition due to these causes and to eggs being washed off by rain are partly effaced when the oviposition curves are fashioned, as is here customary, from twice-weekly egg counts. Occasionally, however, weather conditions are responsible for various features of marked irregularity in the course of oviposition.

Of conditions affecting the plant, the occurrence during florescence of wilting, damage by disease, hail, locusts and other insects, to mention the more important causes, render a crop temporarily or permanently unattractive to the egg-laying moths.

Diversion of moths in response to the greater attraction of a neighbouring crop is the most frequent cause of variations. For example, citrus may be bordered by or interplanted with peas. Of the two, healthy peas in flower appear to exert the greater attraction, as on all recorded occasions the moths oviposited on them to the practical exclusion of adjacent citrus over the period of mutual flowering. Thus too, maize, one of the most highly preferred crops, on coming into tassel may draw the moths away from other crops, both short and long-flowering, at some period or other in their flowering life, with resulting variations from the normal course of laying on isolated crops of the less attractive species.

According to our experience cotton does not occupy a high place in the scale of attraction and when grown in a community of alternative food-plants of the bollworm it is common to find comparatively low, often negligible, numbers of eggs on cotton over long spells of the flowering period, though at the same times the aggregate laying on the preferred species may be of formidable dimensions. Situations of this nature have been noticed particularly as regards native-grown cotton and cotton grown on experiment stations where multiple cropping is in vogue. The subject is reverted to in the following section on native-grown cotton.

On European farms where cotton-growing is a major enterprise the programme for alternative crops rarely permits of continuous " cover " for cotton against bollworm, but occasionally, by design or chance, a sufficient volume of other crops has been present in flower at the right time to absorb partly, even wholly, the attentions of the moths in one or other of the flights. Variations of like nature and effect have been found in respect of other species of food-plants, especially those of long-flowering habit (*cf.* groundnuts). Amongst other effects produced is a skewness of the curve or a breaking off of egg deposition when the influence of counter-attraction is exerted in a large degree.

These investigations were designed primarily in order to gain information of value in devising measures against *Heliothis* as a pest of cotton, and it may be added that they commenced when cotton greatly preponderated in the rainy season and the pertinent oviposition-flowering relationships were perceived most clearly before a fair degree of diversified cropping was introduced, partly as a result of the low price for cotton but also in realization of the need for crop rotation. As the methods and observations advanced parallel with farming developments, it has been possible, using our knowledge of the train of moth flights, to interpret the various courses of oviposition on cotton in terms largely of the relative attraction of moths to sundry crops. Example 2 in fig. 6 now applies for the generality of cotton infestations on European farms because there is a higher degree than formerly of shared oviposition. In fact the difference shown between the courses of flowering, and thus fruiting, in the examples given in that figure is a measure of the difference between the status of *Heliothis* as a pest of cotton when cotton is grown with and without the advantages gained by way of disseminated moth activity.

A certain amount of fluctuation in the moth population per individual crop, especially of the less attractive species, is to be expected as and when moths transfer their laying activities from centres of declining attraction to others then more attractive.* The less the overlap of the flowering periods of the crops in a particular area, the more marked will be the fluctuations in an individual crop. On that account variations in the *shape* of oviposition curves arise, particularly should the influx occur towards the beginning or end of flowering in a given instance. But evidence of violent fluctuations, as based on egg counts, has been rarely forthcoming. Their infrequence is explicable on the grounds, firstly, and as judged from the shape of normal laying curves, that the exodus of moths from a crop is generally gradual; secondly, that most of the moths would be leaving small crop areas that had been of the greatest attraction to spread over wider areas of crop of, as it were, second or third choices, where the consequent rise in egg numbers per acre would not be of great extent. The second statement has particular reference to rain-grown crops in the areas under review when (and where) cotton predominated, but it applies with equal force to the local complexes of winter-irrigated vegetable and orchard crops. The situation could, of course, be reversed and probably is, for instance, in large maize-growing territories where, in view of the short period maize attracts, sudden and large concentrations of moths in the relatively small areas of other crops would be expected.

Except when modified by any of the above circumstances, an alignment of the courses of oviposition and flowering on short-flowering species is exhibited over any period that falls under the curve of a moth flight. Occasions when flowering occurs partly before (or after) and partly under a flight are, however, numerous, and the curves then lose alignment to an extent dependent upon the numbers of moths actively engaged. Either the ascending or descending side of the flight may be overlapped as to time by the flowering curve. Whichever case it may be, the greater number of moths will be engaged in laying as the flowering either waxes or wanes. As a result skewness is imparted to the particular laying curve or a subsidiary peak is created. The most pronounced instances are apparent in data from very short-flowering crops; exaggeration to one side or the other of some of the graphs for maize and sorghum in fig. 2 would exemplify the degrees of variation attributable to the circumstances mentioned. As regards long-flowering crops, the commonest expression of this type of variation is a subsidiary peak of laying, because the crop has experienced or shortly will experience layings of major dimensions according to whether it is, while in flower, receding from or advancing towards the peak period of a moth flight.

The moths in egg-laying discriminate to some extent between varieties and strains of plant species. In some cases, as intimated previously, the discrimination appears to be based only on differences in the vegetative habit of the plants, and doubtless questions of eco-climate are involved; objective, quantitative measures of environmental factors are being sought as regards cotton. In other cases there is evidence of differential response to attraction resident in the plant. Barber has found[2] that sweet maize in Virginia received many more eggs from *Heliothis* than ordinary types of field maize. In plot tests at Barberton we have noted highly significant differences between varieties of field maize in the quantity of eggs received. Evidence, also based on egg counts, strongly suggests that strains of *Cicer arietinum*, *Dolichos* beans and sorghum vary in attraction of the moth on grounds other than those of health, size or habit, vegetative or flowering.*

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*The weight of evidence is against the existence of widespread inter-district movement of moths, which would be a confusing factor.

In the same general connection as the above, we have also to consider the influence wielded by early, medium and late-flowering varieties and strains of a species. When grown in neighbourhood, the oviposition-flowering relationships come into play. As regards lay-outs of randomized plots, prior response of moths to a strain earlier or more abundantly in flower is exhibited, but apparently under a localized incitement to oviposit, eggs at the same time are laid sporadically on the less freely or even non-flowering plants in surrounding plots. As the flowering situation develops the weight of oviposition inclines to other, later strains.

Taken together, responses in the above cases have been perceived mainly during the conduct of experimental plot work. Widely variable courses of oviposition are attributable to them, but they are the result of insect-plant complexities that have been created in one small field area, and they do not apply importantly when the varieties and treatments are sited individually on a broad field basis. They receive mention as being of particular interest to the experimentalist and plant-breeder in view of the extra difficulties they bring about. It is appreciated here that the moulding influences on fruiting behaviour and ultimate yields which ensue from bollworm damage, varying markedly as it does in time and place within plots, requires very careful consideration when judgment is made of the relative merits of strains and treatments.

As stated under Methods and Procedure attempts were made to judge the direction of inter-crop movements of moths. One reason for the endeavour was to learn if moths in passing over cotton from an older to a younger crop of maize, or to another of the more attractive crops, would deposit eggs en route on the cotton—the area of cotton was frequently much larger than that of the alternative crops, especially where the latter were grown as bollworm traps. Cases where cotton was situated diagonally between the trap-crops gave the best indications ; diagonal trails of laying were evident occasionally from target diagrams of the egg counts taken, as stated previously. Sharp, but temporary, increase in the egg population over a band of the intervening cotton was noted and the circumstances may be cited as contributing, in a generally minor degree, to casual variations of the relations under discussion.

Exceptions to the Relationships.

A general exception to the oviposition-flowering relationships occurs when the egg-laying moths can find practically nothing but non-flowering crops. Situations of that sort are found in the early part of growing seasons before plants have advanced much beyond the seedling stage. The eggs are distributed indiscriminately and frequently are placed on the vegetation of plants not otherwise selected as food-plants.

It is also worthy of mention that moths driven out of crops cut or ploughed-in, *e.g.*, lucerne, sunn hemp and other soiling crops, or leaving crops that are losing attraction en masse, *e.g.*, at the close here of the winter crop season, have been known to oviposit heavily on adjacent non-flowering crops, although more distant crops or patches of wild food-plants in flower were available.

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*We have not yet been able to separate cottons purely on evidence of inherent attraction. It is a shrubby plant which displays to the greatest extent those variations in habit to which the moth reacts, and means of eliminating their effect have not yet been devised.

Only two definite cases have come under notice of crops which consistently attract the egg-laying moth when not in flower. They are the chick pea (*Cicer arietinum*) and a strain of *Dolichos lablab*. The *Dolichos* was procured from Southern Rhodesia and is stated to have come originally from Algeria.

The moth lays on both species from early seedling growth onwards to near senescence, although the laying during florescence is noticeably heavier.

Cicer in growth here is a small, compact plant with small, pinnate leaves and is least likely on the grounds of its physical characteristics to attract the moth. Both in and out of flower it appears to be comparatively odourless. From stem and foliage it excretes a mixture of weak acids, the foliage being, at times, decidedly wet. With more knowledge of the bases of attraction this feature may prove to be linked with the enduring attraction of the plant.

The Rhodesian *Dolichos* is a particularly odoriferous plant, even young plants giving off an aromatic scent detectable by man at considerable distances. The scent is lacking in non-flowering plants of the varieties referred to on page 152, and significance possibly attaches to the scent emitted at all times from the Rhodesian *Dolichos*, as the moths certainly respond to volatile extracts (*cf.* page 171).

From time to time eggs have been found in quantity on non-flowering crops of the cow-pea (*Vigna sinensis*) under circumstances which argued for its inclusion with exceptions to the oviposition-flowering relationships. At other times, under similar circumstances, some of the best examples of fit of the respective curves were obtained. Varietal differences and responses are involved, it appears, as one variety, believed to be the Brabham, received eggs only when in bud and flower, whereas records on others of unknown identity number instances of both conformity and non-conformity.

The detectión of the few genuine exceptions noted was incidental to the purpose and scope of the bollworm work as outlined in Part I. Apart from cotton and the attenuated instance of *Dolichos* spp., attempts have not been made to enlarge material and prosecute studies of varietal and strain differences *per se* as regards exceptions.

Utility of the Relationships.

The existence of the following three timing relationships enables the use to the best advantage of trap-crops, insecticides and other means of alleviating the bollworm situation :—

I. The period from planting to the appearance of first flowers varies but little for cotton and most other crops grown as annuals.

II. The onset of oviposition is signalized by the appearance of flowers or their immediate precursors. Florescence is a conspicuous event and provides a most suitable indicator of the beginning of the infestation of an individual crop.

III. The course and duration of the infestation of individual crops are specified approximately by the flowering cycle.

The author is concerned principally with the problem of reducing bollworm on cotton. Previous discussions under Variations and that to follow under Native-Grown Crops provide sufficient indications of the extent to which the egg-laying moths may be diverted by chance or design from cotton. Other references, [13, 15, 16], may be consulted for particulars of the ratios in acreage of cotton to other crops and the preponderance of eggs deposited on the latter when grown under different conditions to take advantage of the timing relationships.

If moths are particularly abundant the quantity of eggs laid on the less attractive species gives rise to a larval population of destructive dimensions and, if the crop can bear the cost, insecticides may be resorted to. Insecticides are most effective against the young larval stages and applications may be timed in the light of the above to secure maximum benefit.

A considerable degree of hand control is obtainable in small areas of cotton because the most effective dates for the collection of larvae can be stated with reasonable accuracy.

Manurial treatments may be adapted to foster vigour of the crop at the time of potential bollworm attack.

The above are instances of the immediate utility of the relationships in attempts at evasion and control. It is evident, however, that the well defined limits of the insect-plant association afford exceptional aids to the study of subjects which bear at longer range on a proper understanding of the bollworm problem. Amongst these subjects prominence must be given to the basic utility of the relations in delineation of the phenological aspects dealt with in Part I. Their value was demonstrated again in the studies reported in Part II on factors affecting the egg population and the status of larval parasitism. The work reported and to be reported is, in fact, replete with examples from the experience of the author and his colleagues of the utility of these relationships. Their advantage to the investigator may be summed up in the statement that parallel and quantitative information may be drawn at will from the insect and plant material present at any time subsequent to the joint onset of flowering and oviposition.

The relation of oviposition with flowering arouses interest in the nature of the attraction and offers initial guides to its study. Something has been said of the moths' susceptibility to differences in vegetative and flowering habit, health, stand of plants and other differences of undetermined character whereby degrees of attraction are constituted. The factors concerned probably modify the influence of deeper-seated attraction.

Recognition by the moth of volatile constituents associated with the flowering condition is certainly suggested. McColloch [11] long ago demonstrated ovipositional response by *Heliothis* moths to twine when treated with maize extract and tied to stakes in the field. Filip'ev[7], who impregnated cotton yarn with acetone and alcohol extracts from maize silk, obtained similar responses.

The author made preliminary tests for olfactory perception by the moths of the unseparated extracts from steam distillates of green maize tassels and the flowers of cotton, citrus, *Dolichos* and tobacco, including peduncles and calyx. Response to odorous constituents remaining in the material after distillation was sought in tests with the expressed liquid and moist plant residues. In order to avoid the more destructive changes induced by the steam treatment, the tests were repeated using alcohol extracts that had been distilled under reduced pressure. The method (enfleurage) of impregnating purified beef fat with the natural flower attars was also employed, as it is probable that the natural scent pattern is broken down when the flowers are subjected to the ordinary methods of distillation and extraction.

In the first tests, balls of cottonwool that had been dabbed with a small quantity of extract were suspended with controls in cages 6 ft. × 4 ft. × 4 ft. In other cases the wools were tied to stakes or green, non-flowering plants enclosed with wire netting. The moths, however, laid only on the wire and woodwork of the cages, and an overriding urge to escape was supposed. Reduced cage areas were then tried and oviposition was found to occur on the wools when moths were confined with them in wire gauze trays 6 inches deep and a yard square. Tests of volatiles in the comparatively still air of such containers are open to many objections but, when used for one night only, and meanwhile deodorized, the trays proved serviceable pending the construction of a more suitable olfactometer.

Circumstances did not permit continuance of this work beyond preliminary stages, but the following further indications that the moths in egg-laying react to scent may be given. The data are from final, single tests in trays. Equal numbers of freshly treated and control balls of wool were inserted at sundown along with four fed and fertilized female moths per tray. Different lots of moths were used in each test.

TABLE VI.

Results from Tests for Ovipositional Response.

	Distribution of eggs (nightly layings in single trays)			
	Wool treated with extract	Wool treated with water	Dry wool	Wire and wood
Unseparated extract from steam distillates :—				
Maize	733	24	0	10
Dolichos	1,090	253	0	28
Cotton	626	390	10	8
Tobacco	217	147	80	64
Unseparated alcohol extract :—				
Maize	834	148	180	36
Cotton	539	255	6	3
Tobacco	205	162	10	40
Citrus	256	84	16	72

Attempts to capture the natural odours in fats were unsuccessful. Indiscriminate layings were recorded in tests of the steam-distilled residue, although in the cases of maize and *Dolichos* it emitted a scent indistinguishable from that of the distilled compounds.*

Response to the tobacco extract was not evident, being inhibited possibly by a strong nicotine odour that is uncharacteristic of the flower scent. Response to the citrus extract was doubtful. Within the limits of the experiment some significance attaches to the other results and they encourage precise investigation.

It will be noted that fed and fertilized females were used in the tests. This was done in an endeavour to eliminate the effects of food and mating stimuli, it being known that food is an essential pre-requisite to mating and normal oviposition.

It cannot be claimed that their food requirements were fully satisfied because, given the opportunity, they will consume overnight more than their own weight of 5% sugar-solution. Most of it is excreted but, if the food is not withdrawn at intervals, the moths die from fermentation of the undigested sugar. In the present instances pairs were allowed nightly access to sugar solution at wicks. Females known to be laying fertile eggs were then withdrawn for purposes of the tests.

It is noteworthy that moths in the presence of the expressed liquid and moist plant residues, which contained sugars, laid indiscriminately. Sugars were present also in the alcohol extracts, but these on exposure dried quickly and the sugars, if detectable by the moth, were probably unavailable. Granting, however, the possibility of attraction to food at the alcohol extracts, it is difficult to reconcile the responses to the distillates with food and mating stimuli. Field observations, suggesting that moths may take food in one species of crop with functioning nectaries, *e.g.*, flowering cotton, and lay on another species where there is little or no likelihood of obtaining food, *e.g.*, maize in green tassel, support a view that oviposition and food responses are distinct. It is interesting to note here that, according to Hampton,[8] the essential oil of the flower is not secreted by the nectaries.*

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*A maize tassel which has hung on the back of a door since 1936 still gives off the characteristic scent. The scent was not pronounced until the tassel had dried out.

The egg-laying moths may be swayed differentially by attractants of a chemical nature which, to them, are more perceptible in the flower scents than in the less complex leaf scents. Given that it is so, the substances perceived must be of common occurrence in the plant kingdom, because the food-plants of *H. armigera* are legion and contain representatives of most of the natural Orders. Even so it is difficult to imagine that the moths in egg-laying are actuated primarily by smell and recognize differences which lie at the base of food-plant preferences. There are, for instance, the facts that the flowers of many species become scentless after nightfall when the moth is engaged in laying ; scents vary in strength and quality according to atmospheric conditions and there are wide differences between species in the production and diffusion of scents within common ranges of those conditions, yet under all kinds of conditions there has been little or no departure from the order of preference as exhibited by egg-laying records ; flowers generally discard attractive devices as soon as fertilization is accomplished ; the flowers of several of the most favoured food-plants are always odourless, or comparatively so, at any rate to man. But in view of experimental data on the extreme sensitivity of the chemoreceptors of insects, perhaps too much importance is attached to the seeming absence of scent in particular instances and questions of scent changes. The nature of the attraction and the means of perception remain to be investigated as a problem of importance not only to bollworm control but to Zoology in general.

Studies of larval nutrition indicate that a diet of flower and fruit parts is essential in many cases for optimum development and the production of large, fecund moths ; optimum opportunity for the reproduction of the species is provided as, through the alignment of flowering and oviposition, the formation and development of the necessary fruit bodies proceeds parallel with development of the larvae from eclosion to maturity. Oviposition rises with increased flowering, and the food is most abundant and of the most suitable range when the larval population is at a peak. Apart from questions of the means of perception, the relationships manifest instinctive behaviour.

Distribution of Oviposition on Native-Grown Crops.

The small and irregular patches of the better lands at their disposal are cultivated by natives at the break of the rains and sown to a succession of various crops either in free stands or intercropped. Usually the lands are contiguous and the situation is one where crop plants of differing habit have overlapping flowering periods.

A priori, a fluctuating attraction for moths was supposed and a high degree of disseminated egg-laying was suspected. Information on these points was sought in the Native Areas of Swaziland.

In general and as compared with conditions in other parts of Africa, the agriculture of the Swazis is primitive and restricted. Maize and sorghum are the principal crops and, as yet, very little cotton is grown. Individuals, however, do grow a wide range of crops, including cotton, and the distribution of oviposition on them was recorded for three seasons in three such situations in Swaziland. The records were taken under the immediate direction of the author's colleague, Mr. H. Hutchinson.

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*Nenyukov[12] reported the presence of minute quantities of aromatic substances in nectar but inferred that they were probably accidental additions from pollen. Aromatic constituents were not found in the nectar from the extra-floral glands of cotton (Parsons[19]).

One example of the distribution found is illustrated in fig. 8. The observations were made in the holding of a native who prepared his lands rather better than is usual, planted in lines and thinned to advantageous spacings—instead of the customary thick and choking broadcast. Sampling was facilitated and comparisons could be drawn on the basis of eggs-per-crop-area.

Owing to the presence of a parasitic weed, *Striga lutea*, there was much irregularity in growth of the maize and sorghum. The better-grown portions amounted to only one-third of the areas under maize and to one-half of the sorghum areas These portions received the bulk of the eggs laid on the two species of crop, but data are reported as for their total acreage in order to indicate the status of their attraction. The weed and its effects are omnipresent in native lands and, as a consequence, the attractive power of maize and sorghum is rarely exerted in a force compatible with their acreage.

Particulars of the acreage, planting dates (where known) and florescence of the crops concerned are given below.

TABLE VII.

Particulars of observed Native Crops.

Crops	Acres	Planting dates and florescence
1st Maize ...	1·00	Planted Oct. 20th, tassels appeared Dec. 18th
2nd ,, ...	1·50	,, Nov. 29th, ,, ,, Jan. 23rd
3rd ,, ...	1·70	,, Jan. 5th, ,, ,, Mar. 2nd
1st Sorghum ...	1·50	,, Oct. 20th, heads ,, Dec. 26th
2nd ,, ...	1·80	,, Nov. 20th, ,, ,, Jan. 20th
3rd ,, ...	2·00	,, Nov. 30th, ,, ,, Feb. 2nd
Groundnut ...	1·50	,, Dec. 30th, flowers ,, Jan. 30th
Cotton ...	4·00	,, Nov. 22nd, ,, ,, Jan. 19th
Tobacco ...	·25	Irregularly in flower Dec. 12th onwards (topped)
Vegetable crops ...	·20	Largely tomatoes and beans, in flower when laid on
Cowpeas ...	·20	Interplanted with maize Dec. 9th, flowers appeared Jan. 31st, flowered until March 6th

Eggs laid on the following wild food-plants were counted—*Acalypha segetalis Cleome monophylla, Datura stramonium, Hoslundia opposita, Nicandra physaloides, Ocimum americanum, Physalis angulata, Xanthium pungens, Solanum nigrum.* These weeds were scattered in characteristic profusion over a total of 2·4 acres of adjacent lands not in crop. The population of the more abundant species was estimated and collective egg numbers on the separate samples were determined.

In fig. 8 a graph of the oviposition on cotton alone is given and, above it, a graph of the aggregate oviposition on the other food-plants ; both represent eggs-per-crop-area. The beginning and end points of oviposition on each of the crops are indicated and reference to their particulars in the Table will show coincidences with flowering. The computed total of eggs laid per crop is inset for purposes of comparison. The ratios in acreage of cotton to alternative food-plants are shown at times of moth abundance.

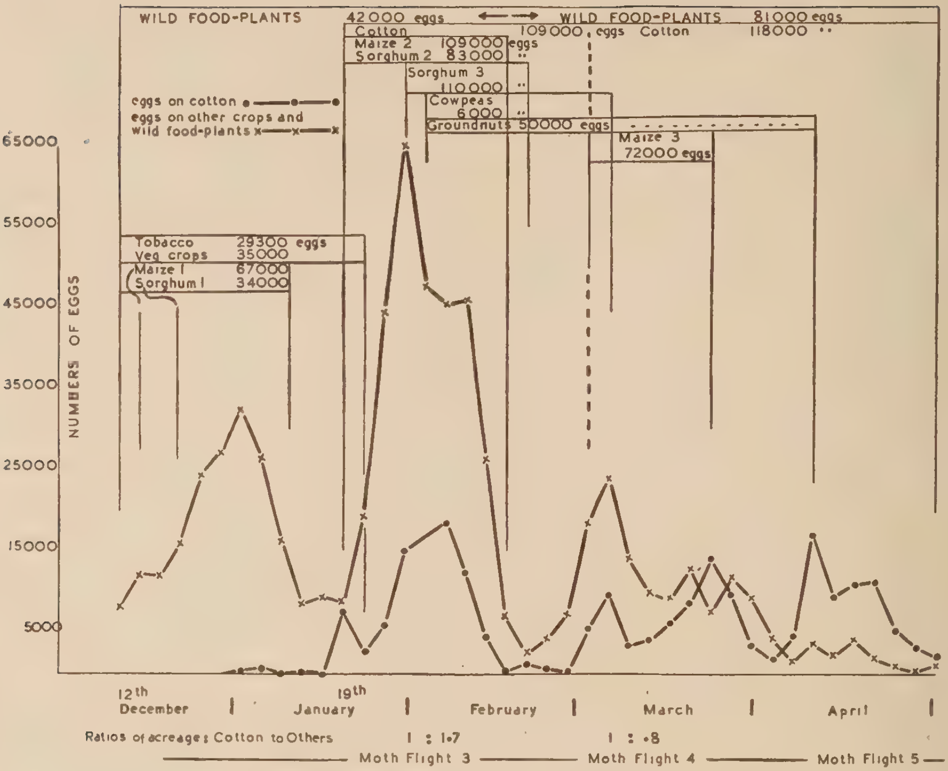

Fig. 8. Oviposition on native-grown crops.

The records in the case illustrated were taken in 1934, a year of exceptionally heavy bollworm attack on the cotton of European growers who had planted little else. In contrast this native's cotton was practically undamaged—it received only 3 eggs per plant* in the first half of its flowering life, during which the major part of the bolls giving yield are set. In this year of bollworm outbreak there was in fact not much evidence of the pest on any of the crops in the case reviewed, owing to the degree of egg dissemination. As is usual here, the moths were partial to the maize and sorghum, but the numbers of eggs deposited on them are unduly impressive because the mortality of maize and sorghum-bred larvae is ultra-extensive.

The instance quoted reveals the extent to which eggs are disseminated over the small areas of the various crops grown by natives. It serves to explain the minor incidence of *Heliothis*, as reported from time to time, in respect to native-grown cotton here and in other parts of Africa—especially in those parts where systems of the most diversified cropping are established in closely settled communities. Workers in the Central African belt of territories and Nigeria have attributed the comparative absence of this bollworm there to counter attractive influences. The information obtained in the above instances would seem to confirm their views. Should the area under cotton in native territories be increased at the expense of one or other of the preferred food-plants, it is to be expected that *Heliothis* would turn more to cotton.

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*29,400 plants were estimated to be present on the 4 acres of cotton and 109,000 eggs were computed to have been laid on the cotton between 31st December and 9th March. The vertical broken line over 9th March in the figure roughly divides the productive flowering life into two halves.

In the above connection it is worthy of mention that there is evidence that a species of crop which is especially attractive in one country may exhibit little or no attraction in another country. As one instance of this phenomenon, the moth in the Sudan appears to ignore maize, including imported strains elsewhere highly attractive (Bedford[4]). Determination of the egg-laying proclivities of the moth as regards the crops associated with cotton in the multiple-cropping systems of any area where cotton might displace or reduce other crops, is a step that might be well rewarded.

Summary.

Studies of the food-plant associations of *Heliothis armigera* have elicited the information that, for all practical purposes, egg-laying may be considered as confined to the period of florescence. Evidence of coincidence of the oviposition and flowering curves is submitted for 21 species of short-flowering crops and 8 species of long-flowering crops. All told, records taken in nearly 1,000 crops have been consulted for the conclusions drawn.

As regards short-flowering species, the peaks, as well as the confines, of the oviposition and flowering curves are related closely. But oviposition on long-flowering species may decline while flowering is still in progress, or two or more waves of oviposition may be evident according to the number of moth flights spanned by the flowering period. The courses of oviposition on long-flowering species of crop in the given instances are interpreted through knowledge of the train of moth flights : although egg-laying in quantity occurs within the flowering period, peak layings frequently are not aligned with maximum flower production because the calendar times of moth flights are displaced in relation thereto.

Variations of the relationships are noted and their causes discussed, *viz.*, the influence of counter-attractive crops, fluctuations in the moth population, overlap of flowering and moth flight curves, inter-crop movement of moths, discrimination by the egg-laying moths between varieties and strains of a plant species—diversion of moths in response to the greater attraction of a neighbouring crop is the most frequent cause of variations, and examples are given with special reference to cotton. Several of the causes of variation operate in layouts of randomized plots and in their results increase the difficulties of the experimentalist and plant-breeder to a degree that they may fail to appreciate when judging the relative merits of strains and treatments.

Exceptions to the relationships are noted. Their detection was incidental to the purposes and scope of the work on bollworm food-plants at hand. Attempts have not been made to enlarge material and prosecute studies as regards exceptions *per se.*

Attention is drawn to the utility of the relationships in respect to (*a*) their immediate utility in attempts at evasion and control, (*b*) the exceptional aids they afford to the study of subjects bearing at longer range on a proper understanding of the bollworm problem, (*c*) their offer of initial guides to study of the nature of the attraction. In connection with (*c*), the results of preliminary tests for olfactory perception by the moths of steam distillates and alcohol extracts from flower materials from different sources are communicated, as they encourage further and more precise investigation. It is suggested that food and oviposition responses are distinct. Whether the moths are actuated primarily by perception of the more complex flower scents and recognize differences that lie at the base of food-plant preferences remains to be established. It is, however, noteworthy that the timing of oviposition with flowering results in the larvae having access to food which favours optimum reproduction of the species. Thus, apart from questions of the means of perception, the relationships manifest instinctive behaviour.

Finally, particulars are given of the times and extent to which eggs were disseminated on a number of flowering crops and wild food-plants in small acreages on a native holding in the Swaziland Protectorate. The cotton received a comparatively light laying (the year was one of exceptionally heavy bollworm attack on unprotected European-grown cotton), and the findings would seem to confirm the views of workers in other parts of Africa that counter-attractant influences in the multiple-cropping systems of natives there serve to protect the cotton from this pest. Possibilities that the area of native-grown cotton might be enlarged at the expense of preferred food-plants of *H. armigera* with a consequent increase in its status as a cotton pest are touched on.

Acknowledgments.

Some of the records used for exemplification and many of those consulted in support of the data in the paper were taken under the immediate direction of the author's colleagues, Mr. P. A. Bowmaker and Mr. H. Hutchinson, in Natal and Swaziland respectively. It is desired to acknowledge again their association and most helpful co-operation over a number of years in this work.

Grateful acknowledgments are due also to my colleague, Mr. Joseph Marshall, who supplied a large quantity of data on the oviposition-flowering relationships from his independent observations.

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BIONOMICS AND CONTROL OF THE INDIAN SUGAR-CANE LEAF-HOPPER, *PYRILLA PERPUSILLA*, WLK. (RHYNCHOTA, FULG.) IN THE PUNJAB.

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(Plate VI.)

1. Introduction.

Pyrilla perpusilla, Wlk., was found in the Punjab for the first time in 1917 at Lahore (Misra, 1917). Four years later it was found damaging maize (*Zea mays*) at the Agricultural Farm, Lyallpur. It was on the introduction of soft and broad-leaved varieties of sugarcane (*Saccharum officinarum*) in 1920, however, that this insect assumed the rôle of a serious pest in the Punjab. At present it is one of the most destructive of our sugar-cane pests.

2. Distribution and Food-plants.

P. perpusilla is widely distributed in the Punjab, where it has been recorded from the following localities: Ferozepur, Gurdaspur, Gurgaon, Gujranwala, Hissar, Hoshiarpur, Jullundar, Kangra, Karnal, Ludhiana, Lyallpur, Montgomery, Patiala and Rohtak. Outside the Punjab it has been recorded from the following places; Cawnpur (United Provinces); Nagpur (Central Provinces); Pusa, Chapra (Bihar & Orissa); Bassein, Kasandra (Bombay Presidency); North Arcot, Coimbatore (Madras Presidency); and Travancore State (Misra, 1917); North Bengal (Distant, 1906); and Palure (Fletcher, 1919).

In addition to sugar-cane it also feeds on the following food-plants according to the season :—

Winter.	*Summer.*
Wheat (*Triticum* spp.).	Chari (*Andropogon sorghum*).
Barley (*Hordeum vulgare*).	Maize (*Zea mays*).
Oats (*Avena sativa*).	Bajra (*Pennisetum typhoidum*).
Swank grass (*Panicum colonum*).	Sudan grass (*Andropogon sorghum* var. *sudanense*).
Buru (*Sorghum halepense*).	Guinea grass (*Panicum maximum*).
	Buru grass (*Sorghum halepense*).

P. perpusilla thrives on all the above-mentioned alternative host-plants excepting guinea grass and buru grass, on which it just manages to eke out an existence. Wheat is its principal host-plant in winter, while the late ripening varieties of oats serve as important hosts during April-May.

The pest is often found on the following plants also, both in the nymphal and in the adult stages :—Kraila (*Momordica charantia*), bhindi (*Hibiscus esculentus*), savi tori

(*Luffa egyptica*), tinda (*Citrullus vulgaris* var. *fistulosus*), halwa kaddu (*Cucurbita pepo*), rice (*Oryza sativa*), cauliflower (*Brassica oleracea cauliflora*), raddish (*Raphanus sativus*), bathu (*Chenopodium murale*), cholae (*Amaranthus viridis*), tandla (*Digeria arvensis*), lehli (*Convolvulus arvensis*), dab (*Eragrostis cynosurus*) khabal, (*Cynodon dactylon*), palwa (*Andropogon pertusum*), siru (*Imperata arundinacea*). But as it was not known whether the pest fed on these plants or not, the question was investigated. For this purpose the nymphs were sleeved on the plants in the field in 1930 and 1931. They died within 6–8 days in summer and in 28–81 days in winter, before reaching maturity. Thus it would seem that these plants are used by the nymphs only as resting places while migrating to their food-plants.

3. Description of Various Stages.

Egg.—Length 1 mm., greatest breadth 0·47 mm. Elongate oval; chorion smooth; pale white to light bluish when freshly laid, developing an ochraceous brown tinge before hatching: those laid during November–December usually develop a fuscous tinge before hatching.

First-stage nymph.—Length (excluding anal threads) 1·1 mm., greatest breadth (metanotum) 0·6 mm., length of anal threads 1·3 mm. General colour of the body varying with the season: greenish white in summer, dark fuscous in winter. Compound eyes dragon red. Antenna two-jointed, first joint short and stout, second sub-globose with 4 sensoria located dorsally. Frons with a double row of small, orbicular spots along each lateral margin, there being 8 spots in the anterior, and 3 in the posterior row. Thorax with granular spots on either side of the dorso-median longitudinal carina which are situated as follows: 6 on pro-, 4 on meso- and 2 on metanotum.

Second-stage nymph.—Length (excluding anal threads) 2·4 mm., greatest breadth (metanotum) 1·0 mm., length of anal threads 4 mm. General colour of the body varying with the season: pale white to light brown during summer, dull brown (occasionally suffused with dark brown) during winter, excepting the first five abdominal segments which are straw-brown with a prominent chocolate-coloured stripe along the lateral margin. Anal threads whitish basally, vinaceous-fawn distally. Anterior femora and tibiae broadly ampliated; posterior tibiae with 8 chocolate-tipped spines at their distal extremities; first tarsal joint of the posterior tarsus armed with 3 spines distally.

Third-stage nymph.—Length (excluding anal threads) 3·2 mm., greatest breadth (metanotum) 1·5 mm., length of anal threads 6·0 mm. General colour of the body pale brown (rarely light bluish) during summer, white straw-brown suffused with fuscous (the first 4 abdominal segments being fuscous brown) during winter. Compound eyes greyish green with a number of minute blood-red spots and with a prominent black spot situated posteriorly. Anal threads light vinaceous-buff to light vinaceous-fawn. Anterior and intermediate femora and tibiae broadly ampliated; the first tarsal joint of the posterior legs thicker than the second, being subequal in length.

Fourth-stage nymph.—Length (excluding anal threads) 3·5 mm., greatest breadth (metanotum) 1·4 mm., length of anal threads 5·5 mm. General colour of the body tawny ochraceous (rarely suffused with light bluish) during summer, dull straw-coloured suffused with fuscous and ornamented with two chocolate-coloured stripes intercepted by orange chrome patterns at the abdominal intertergal joints during winter. Frons with a double row of ochraceous, orbicular spots along each lateral margin, there being 9 spots in the anterior, and 3 in the posterior row. Anal threads vinaceous buff. Anterior and intermediate tarsi two-jointed and posterior tarsi three-jointed. Posterior tibiae with a stout median spine and a cluster of 15–16 chocolate-tipped spines distally.

Fifth-stage nymph.—Length (excluding anal threads) 4·3 mm., greatest breadth (across wing-pads) 2·3 mm., length of anal threads 7·1 mm. General colour of the body similar to that of the fourth stage nymph : vertex tawny ochraceous variegated with irregular light fuscous blotches during winter. Thorax ornamented with a longitudinal dorso-median white streak and the abdomen with orange-chrome and dark chocolate stripes separated by a white stripe, all situated dorso-laterally. Wing-pads dark-brown, extending up to 5th abdominal segment ; dark brown during winter with two basal globular spots. Anal threads vinaceous buff. Second joint of the anterior and intermediate tarsi much longer than the first ; the first joint of the posterior tarsi sub-cylindrical and equal in length to the 2nd and 3rd joints together.

Adult.—Distant (1906) describes the adult as follows :—

" Body and legs ochraceous, paler beneath than above ; tegmina yellowish-white, semi-opaque, the apical area and outer claval margin speckled with minute black spots ; wings pale hyaline ; the dorsal ridge to cephalic process is much less prominent in front of the central transverse ridge than behind it.

Length (excl. tegm.) 9 mm., exp. tegm. 18 mm."

4. Life-History.

The adults are fairly long-lived, and 26 individuals observed from emergence to death lived from 27 to 130 and 200 days, with an average of 80, the females averaging rather longer than the males.

During the period from May 1931 to May 1932, 3,759 adults were collected from the fields to study the proportion of sexes ; of these 2,437 were males and 1,322 females.

The duration of the pre-oviposition period depends upon the season : during April–October it lasts for 13–25 days, with an average of 19 days, while during November–December it lasts for 24–47 days, with an average of 32 days.

A female dies soon after oviposition during summer but lives for a long time during winter. For example, during the period from April to October in each year during 1931–1935, females lived for 1–9 days, while during November–March in each year during 1931–1935, they lived 50–118 days.

The eggs are laid in clusters, each cluster having 20–50 eggs ; the highest number recorded in a cluster being 63. A female takes 32–64 minutes to lay an egg-cluster. The place of oviposition depends upon the season as well as upon the intensity of the outbreak : during summer the eggs are usually laid on the underside of a leaf close to the mid-rib, while during the cold season (November–December) they are mostly laid on the inner side of the sheathing bases of the leaves ; but during years of serious outbreak eggs may be laid on any part of the food-plant, and may even be laid indiscriminately on roadside trees such as pipal (*Ficus religiosa*), shisham (*Dalbergia sissu*), hedge-row plants (*Duranta* sp.), weeds and even on the soil. At Sonepat (District Karnal), in November 1934, a field was so thickly covered with eggs that from a distance it appeared to be white-washed.

The number of eggs laid by a female depends upon the season, the least number being laid when it is very cold, *e.g.*, December–March (Table I). The interval between each laying during April–October is 2–6 days, during November–December it is 7–25 days, and during November–January 57–126 days.

Monthly oviposition records of 274 individuals of *P. perpusilla* on sugar-cane were obtained during 1931–35, and 100 of these are summarised below :—

TABLE I.

Period of egg-laying	Minimum no. of eggs laid	Maximum no. of eggs laid	Average no. of eggs laid
January	12	29	16·50
February	18	42	28·65
March	1	27	11·71
April	64	192	130·0
May	92	444	219·9
June	49	188	94·50
July	11	96	55·71
August	32	144	80·26
September	93	285	169·5
October	78	475	190·28
November	26	196	92·50
December	12	87	39·12

It will be observed that a female lays the largest number of eggs during May and October. The total number of eggs laid by a female during her life-time was observed in 100 specimens and ranged from 37 to 773, with an average of 303.

Eggs are laid by instalments, the oviposition period occupying 15–126 days. At each sitting a female lays 20–63 eggs, the full quota of her eggs being laid in 4–20 sittings.

Eggs laid in April–October hatch out in 7–12 days, while those laid during mid-October–mid-November and mid-November–December take 20–29 and 25–41 days respectively to hatch.

There are five nymphal instars, the duration of which varies according to the season. From April to September the separate stages averaged 7–11 days each, with a total period of 28–69 days; those hatching in October averaged 17–41 days, with a total period of 160; and those hatching in January 14–32, with a total of 103 days.

In order to find out the number of broods in a year continuous rearing was done. The insect was caged or kept in a sleeve on sugar-cane plants in the fields. These observations showed that the pest has 3–4 broods in a year. The first two broods are clear-cut, but the 3rd and 4th (when present) overlap each other.

5. Seasonal History.

The adults are common towards the end of March. They lay eggs on the sprouting sugar-cane in the third week of April in S.E. Punjab (Sonepat) and in the last week of April in the Canal Colonies (Lyallpur), sub-montane region (Gurdaspur) and Central Punjab (Jullundur). From May to December all stages of the pest are met with in the fields. During the period from January to the third week of March the insect is mostly present in the nymphal stage. The eggs that are found in the fields in January and the beginning of February are usually those that are laid in November–December. When sugar-cane is harvested about the end of February the nymphs transfer themselves to wheat, barley, oats, guinea grass and " buru." They become adults during end of March and the first half of April. When wheat and oats are harvested in April–May, they migrate to sugar-cane, maize and " chari " (sown for fodder) at any time in the second half of April (fig. 1).

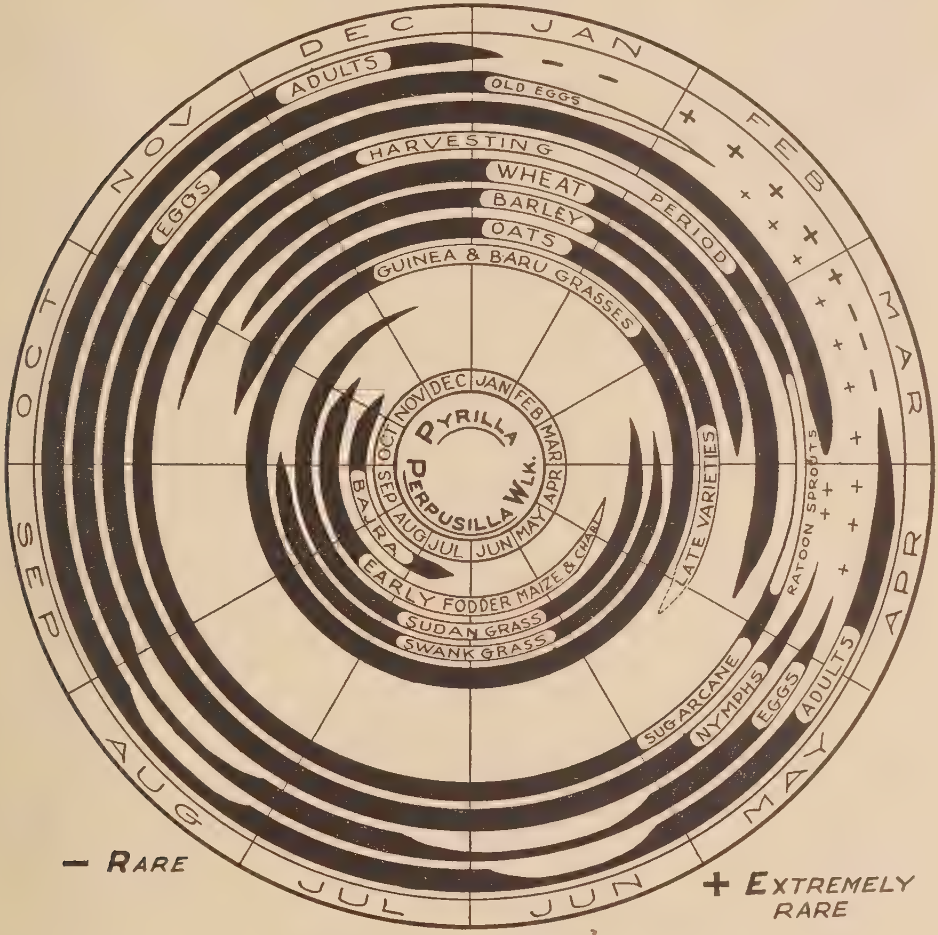
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
ADULTS
OLD EGGS
EGGS
HARVESTING PERIOD
WHEAT
BARLEY
OATS
GUINEA & BARU GRASSES
LATE VARIETIES
RATOON SPROUTS
SUGARCANE
NYMPHS
EGGS
ADULTS
BAJRA
EARLY FODDER MAIZE & CHARI
SUDAN GRASS
SWANK GRASS
PYRILLA PERPUSILLA WLK.
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
— RARE
+ EXTREMELY RARE

Fig. 1. Seasonal history and food-plant calendar.

6. Damage.

Both adults and nymphs do damage, sucking the juices usually from the underside of a leaf. The attacked leaf becomes pale and wilted, and the growth of the plant is checked. Besides, the pest produces " honeydew," which falling on the lower leaves provides an excellent substratum for the development of sooty mould (*Capnodium* sp.), which interferes with the proper functioning of the leaves. Also, cattle refuse to feed on sugar-cane, maize and " chari " damaged by this pest.

In order to study the effect of feeding on the quality of the juice of an attacked plant, the following experiment was carried out during 1929–30 and 1932–35.

Sugar-cane stools identical in every way were selected in a field and were enclosed in two cages. One of these cages was kept entirely free from the pest and in the other an attack of the severest intensity was produced artificially. The results are given in Table II.

We are indebted to Dr. P. E. Lander, Agricultural Chemist to Government, Punjab, Lyallpur, for the chemical analysis of the cane samples. The definitions given below of the chemical terms employed have been kindly furnished by Pundit Lal Chand Dharmani, of the Agricultural Chemistry Section, Lyallpur.

1. Sucrose.—Crystallisable cane-sugar : higher the better.
2. Glucose.—Uncrystallisable sugar : lower the better, as it adversely affects the crystallisation of sucrose, thereby affecting the recovery of cane-sugar.
3. Glucose ratio.—Is the proportion of glucose to sucrose expressed as percentage : the lower the ratio the better it is.
4. Purity co-efficient.—The ratio of cane-sugar to total solids in juice : the higher the better.

TABLE II.

Showing effect of feeding of P. perpusilla *on sugar-cane* (*variety Co.* 223).

Period of experiment	Description of sample	Percentage on sugar-cane				Glucose ratio	Purity efficient
		Juice	Total solids				
			Sugars		Non-sugars =wax, mineral matter, etc.		
			Sucrose 1	Glucose 2		3	4
27.viii–14.i ...	Control ...	68·33	8·35	0·53	2·15	6·35	75·70
	Attacked ...	68·18	5·49	0·96	1·14	17·49	72·34
27.iii–21.i ...	Control ...	70·07	8·29	1·06	0·40	12·29	85·10
	Attacked ...	70·50	5·16	1·56	2·01	30·23	59·10
27.vii–4.ii ...	Control ...	70·10	9·21	0·50	2·14	5·43	77·70
	Attacked ...	68·30	6·80	1·26	2·32	18·53	65·50
27.vii–11.ii ...	Control ...	70·10	8·70	0·60	2·13	6·90	76·10
	Attacked ...	72·50	5·89	0·97	2·40	16·47	63·50

It is seen from the above table that sucrose was reduced by as much as 34·2 per cent., while the glucose ratio was 3 times greater in the attacked sample. Thus *P. perpusilla*, Wlk., adversely affects the quality of the cane.

7. Susceptibility of different Varieties of Sugar-cane.

Varieties of sugar-cane evolved at Coimbatore (South India) together with " ponda " and " katha " are grown commonly in the Punjab. The more popular varieties during 1931–35 were the following : Co. 205, 213, 223, 244, 285, 290, 301, 312, 313. In order to find the varietal preferences of *P. perpusilla*, the following method was adopted : an insect store-box was used to capture the nymphs on the infested leaf in order to determine their population per unit area of 25 sq. inches. Table III presents the results of these observations, which were made at Gurdaspur and Lyallpur.

TABLE III.

Name of variety	Character of leaf and stem	No. of observations (November)	No. of insects captured		
			Minimum	Maximum	Average
Co. 223 ...	Broad, succulent leaves, stem soft and thick	11	114	315	198
" Ponda " ...	,, ,, ,, ,,	25	103	344	191
Co. 213 ...	,, ,, ,, ,,	11	78	183	123
Co. 285 ...	Narrow, hard, non-succulent leaves, stem hard and thin	10	22	41	30
Co. 205 ...	,, ,, ,, ,,	11	11	49	31
" Katha " ...	,, ,, ,, ,,	13	3	28	12

Table III shows that *P. perpusilla* prefers those varieties of sugar-cane which have broad, fleshy succulent leaves and thick and soft stems. This conclusion is further supported by observations on the relative numbers of eggs laid on different varieties of sugar-cane (Table IV), which were made at the Sugar-cane Research Station, Risalewala (Lyallpur), the area of the plot from which counts were made having been 1/40th of an acre.

TABLE IV.

Variety of sugar-cane	Character of leaf and stem	May, 1936			May, 1937		
		No. of plots examined	Egg clusters		No. of plots examined	Egg clusters	
			Total	Average per plot		Total	Average per plot
Co. 421 ...	Broad, succulent leaves, stem soft and thick	12	347	29	4	485	121
Co. 323 ...	,, ,, ,, ,,	18	236	13	1	11	11
Co. 331 ...	,, ,, ,, ,,	16	49	3	7	161	23
Co. 313 ...	,, ,, ,, ,,	19	276	14	4	27	7
Co. 312 ...	,, ,, ,, ,,	17	373	24	8	106	13
Co. 395 ...	Narrow, non-succulent leaves, stem hard and thin	20	118	6	8	102	13
Co. 396 ...	,, ,, ,, ,,	5	47	9	1	8	8
Co. 285 ...	,, ,, ,, ,,	26	147	5	15	147	9

It is evident that the largest number of egg-clusters are laid on varieties with broad and succulent leaves and least on those which have narrow and thin leaves. This is further supported by the data presented in Table V. The females were sleeved in the open to study the number of eggs laid by them during the period from September to March in each year from 1931–36.

TABLE V.

Variety of sugar-cane	Character of leaf	No. of females sleeved	Total no. of eggs laid	No. of eggs laid per female
Co. 213 ...	Broad leaves	30	4,838	161·20
Co. 223 ...	,, ,, ...	44	6,298	143·13
" Katha " ...	Narrow leaves	34	2,639	77·61
Co. 285 ...	,, ,, ...	30	2,346	78·20

8. Natural Enemies.

The following are the natural enemies of *Pyrilla perpusilla* :—

Egg parasites :—*Ooencyrtus papilionis,* Ashm. (Hym. Encyrtidae), *Tetrastichus pyrillae,* Craw. (Hym. Eulophidae).

Nymphal parasites :—*Lestrodryinus pyrillae,* Kieff. (Hym. Dryinidae), *Pyrilloxenos compactus,* Pierce (Col. Stylopidae).

Predators :—*Brumus suturalis,* F., *Chilomenes sexmaculata,* F., *Coccinella septempunctata,* L., *C. undecimpunctata,* L. (Col. Coccinellidae) ; *Epipyrops* sp. (Lep. Epipyropidae).

Egg Parasites.

These are rare during January–July and are most abundant during August–December (Table VI). In April 1934, out of 58,472 eggs examined at Sonepat only 26 eggs (*i.e.* 0·004 per cent.) were parasitised, and during April–May 1935, out of 2,937,173 eggs examined at the same locality only 188 (*i.e.* 0·0006 per cent.) were parasitised.

TABLE VI.

Year	Locality	August		September		October		November		December	
		No. of eggs examined	Per-cent. parasitised	No. of eggs examined	Per-cent. parasitised	No. of eggs examined	Per-cent. parasitised	No. of eggs examined	Per-cent. parasitised	No. of eggs examined	Per-cent. parasitised
1926	Lyallpur ...	1,072	9	550	32	116	42	701	15	1,170	4·6
1928	Gurdaspur ...	1,173	29	2,527	36·1	967	32·2	825	27·6	—	—
1929	Lyallpur ...	—	—	1,679	13·3	1,962	24	1,728	24·5	873	9·3
1930	,, ...	—	—	1,308	26	3,370	38	4,872	33	3,199	12·2
1931	,, ...	2,241	19	2,071	27	5,433	52	1,616	79	1,454	36
1932	,, ...	838	30	5,133	40	2,811	50	3,507	70	875	49
1933	,, ...	—	—	2,012	71·5	1,094	77·9	737	51·2	891	20·8
1934	,, ...	453	28	3,545	46	1,865	47·6	256	42	—	—
1935	Sonepat ...	2,926	0·03	5,021	41	4,908	33·9	13,036	12·2	29,443	17

This shows that during September and November up to 71·5 and 79 per cent. of the eggs respectively are liable to be parasitised.

The life-cycle of *Ooencyrtus papilionis* during August–September is completed in 10 days, during October–November in 16–21 (average 17·42) days, during November–January in 21–64 (average 25·4) days ; that of *Tetrastichus pyrillae* during April–May and September–October lasts 11 days, during October 17–22 (average 19·5) days, during November 20–23 (average 22·5) days.

Nymphal Parasites.

Although present throughout the year *Lestrodryinus pyrillae* is common during April–December. Observations carried out during 1930–1936 indicate that it never parasitises more than 9·7 per cent. of the host nymphs. The attacked nymph is recognised by the gall-like cyst or thylacium (containing the parasite) which it bears. *L. pyrillae* has a hyperparasite, *Cheiloneurus* sp. (Encyrtidae), which is common from November to March. The highest parasitism occurs in March to May (average 7·8 per cent.), and the greatest number of eggs laid by a single *Lestrodryinus* was 42. During April–October the life-cycle is completed in 37–40 days and during October–April in 122–157 days.

In years of outbreak up to 66 and 86 per cent. respectively of the nymphs and adults of *P. perpusilla* have been found bearing 1–16 cases of the Stylopid parasite, *Pyrilloxenos compactus*, Pierce, as shown in the following table, based on observations at Sonepat in 1935.

TABLE VII.

Month	Adults		Nymphs	
	No. examined	Percent. stylopized	No. examined	Percent. stylopized
February	57	7	1,191	0·5
March	114	14·89	412	30·00
April	196	37	134	86
May	51	37	220	10
June	32	66	19	63
July	—	—	28	35
August	89	1·1	230	2·6
September	184	2·1	611	0·1
October	43	2·3	—	—
November	191	2·1	7,994	0·07

To study the life-cycle of the Stylopid, the following method was adopted :—On their emergence from the brood-canal aperture of the female the triungulins were lifted (under a microscope) on a fine brush and placed on *Pyrilla* nymphs reared in confinement. They penetrated into the body of the nymphs through the ventral side of the intersegmental membranes of the abdomen. The life-cycle was thus found to occupy 39–45 days. *Pyrilloxenos* is active throughout the year, having five generations.

According to Misra (1917) the parasitised adult hopper succumbs within two hours of the emergence of the male Stylopid. Our experience is vastly different: the adult hopper was none the worse for the emergence of the male parasite, for we have seen 2–5 male *Pyrilloxenos* emerging from a single adult hopper, which continued to live normally afterwards. The females, on the other hand, became sterile, while the nymphs died within 30–37 days of stylopization.

Predators.

The Coccinellid beetles, *Brumus suturalis* and *Chilomenes sexmaculata*, feed voraciously on the eggs of *Pyrilla*, the former being the commoner and more important. They are abundant during April–May. *Coccinella septempunctata* and *C. undecimpunctata* may also occasionally be found in canefields feeding on the eggs of *Pyrilla*.

The caterpillars of a moth of the genus *Epipyrops* were found in large numbers, in October 1939, only at Sonepat feeding upon the adults and nymphs of *P. perpusilla*.

9. Control Measures.

Removal of dry sheathing Leaves during Winter and its Effect on Oviposition.

It has been pointed out above that during winter the pest usually lays eggs on the inner side of the dry sheathing leaves of sugar-cane. Observations were carried out, in September 1935, at Sonepat to study the effect of removing such leaves on the oviposition of *P. perpusilla*. The variety of cane selected was Co. 244, and many of the canes, after being stripped, were tied up together in the usual manner to prevent lodging.

TABLE VIII.

Dates of observation	Area of sugar-cane examined	Stripped	Control	Remarks
		No. of eggs	No. of eggs	
14.xi	30¼ sq. ft.	146	3,024	Canes not tied
27.xi	,, ,,	3,721	5,443	,, tied
		327	—	,, not tied
17–19.xii	,, ,,	2,069	7,107	,, tied
		294	—	,, not tied

Table VIII shows that the number of eggs laid on stripped canes is far less than on the control, but if, after stripping, the canes are tied up together in the usual manner they get much more highly infested than those stripped canes which are left untied.

Destruction of Adults before Oviposition.

Nymphs that have spent the winter on wheat develop into adults by the middle of April in south-eastern Punjab and by the third week of April in the Canal Colonies and central Punjab. When the wheat is harvested, they migrate for egg-laying to sprouting sugar-cane and to maize and "chari" sown for fodder. They should be destroyed before oviposition by collecting them with hand nets.

It was found that six men working for 8 hours a day could practically free of adults an acre of sugar-cane in which their population ranged from 6,800 to 7,200 per acre, the cost being about one rupee (1s. 4d.) an acre. Only 1–2 per cent. of the adults escaped destruction in this way.

Destruction of Eggs.

The eggs, because of their whitish fluffy covering, are very conspicuous on green leaves. They should be crushed by passing the egg-bearing leaves between the thumb and fore-finger (both wrapped in muslin cloth separately to protect them from injury from rough leaves). It has been found that four men working for a day of 8 hours can destroy eggs from an acre of sugar-cane at a cost of *Rs*.1/11/– to *Rs*.2/4/– (2s. 3d. to 3s.) an acre, depending upon the intensity of oviposition.

Destruction of Nymphs.

Of the various mechanical methods tried a new hopperdozer (evolved by us) gave the best results. Its essential features are shown in Plate VI. This machine is very effective against nymphs feeding on wheat when it is 1¼–1½ ft. in height, during February. The leaves are cleaned by brushes inside the machine, and the nymphs swept into a container which has a small quantity of calcium cyanide in it. By this means the hopper population on an acre can be reduced in 2½ hours from about 100 to only 2·5 per sq. ft.

Insecticidal Control.

If the pest is not controlled during April–May by any of the above-mentioned methods, then an insecticide has to be used. Of the various insecticides tried the following gave excellent results :—

Nicotine dust, when prepared according to the following formula, gave the highest mortality—

Nicotine sulphate	1 lb.
Ashes	10 ,,
Lime	19 ,,
Sulphur	10 ,,

The kill was 100 per cent. on both wheat and sugar-cane, the cost on the latter crop amounted to *Rs*.6/10/– (8s. 10d.) an acre, and *Rs*.6/4/– (8s. 4d.) on wheat.

Two men with a " Torpedo " duster could cover an acre of wheat in about 1½ hours, while one man with a " Blue Beauty Peerless " duster could dust an acre of nearly full-grown sugar-cane in 2–2½ hours.

Nicotine sulphate-fish oil soap mixture, when prepared according to the following formula, also gave 100 per cent. mortality—

Nicotine sulphate	4 oz.
Fish oil soap	2 lb.
Water	50 gall.

Two men with a " Four Oaks " sprayer could spray an acre of wheat in 4–6 hours, at a cost of *Rs*.3/5/– (4s. 5d.), whereas an acre of sugar-cane would cost *Rs*.6/9/– (8s. 9d.).

The two insecticides gave the best results during November–March. Being expensive, they should only be used in cases of exceptionally heavy attack.

The cost of dusting and spraying is practically identical. The labour required for the preparation of the spraying mixture and for spraying, however, is much more than dusting. Moreover, it was found easier and more convenient to dust full-grown sugar-cane than to spray it. Further, when sugar-cane is ripe, 15–20 canes are tied up together to prevent them from lodging, and in this condition it is not possible to spray the insects settled amongst the tied-up canes.

Summary.

Pyrilla perpusilla, Wlk., is one of the most destructive sugar-cane pests in the Punjab. It is widely distributed and, in addition to sugar-cane, it also feeds on wheat, barley, oats, maize, " chari " and a number of grasses.

Descriptions of the egg, nymphal and adult stages are given.

A female can lay 773 eggs in its life-time. The eggs are laid in clusters on the food-plants and are covered with whitish fluffy material. The egg stage occupies 7–12 days during April–October and 20–41 days during November–March. There are five nymphal instars. The nymphal stage occupies 24–65 days during April–September and 78–208 days during October–March.

Both adults and nymphs do damage. They prefer to feed on those varieties of sugar-cane which have broad, fleshy and succulent leaves and thick, soft stems. As a result of their feeding sucrose is reduced by as much as 34·2 per cent., while the glucose ratio may be trebled.

The pest is parasitised by the following insects :—*Ooencyrtus papilionis*, Ashm., *Tetrastichus pyrillae*, Craw., and *Lestrodryinus pyrillae*, Kieff. (Hymenoptera) ; and *Pyrilloxenos compactus*, Pierce (Stylopidae). The following are predacious upon it : *Brumus suturalis*, F., *Chilomenes sexmaculatus*, F., *Coccinella septempunctata*, L., and *C. undecimpunctata*, L. (Col.), and *Epipyrops* sp. (Lep.). The incidence and duration of the life-cycles of these parasites and predators are given.

To control the pest the following measures are suggested :—(1) Destruction of the adults by hand nets during April ; (2) destruction of the eggs by crushing during April ; (3) destruction of the nymphs by a new hopperdozer during November–March ; (4) dusting with nicotine dust or spraying with nicotine sulphate-fish oil soap mixture.

Acknowledgment.

The problem was suggested by K. B. M. Afzal Husain, Entomologist to the Government of Punjab (at present Vice-Chancellor of the Punjab University, Lahore) to whom we wish to express our sincerest thanks for his helpful advice and guidance during the progress of the work.

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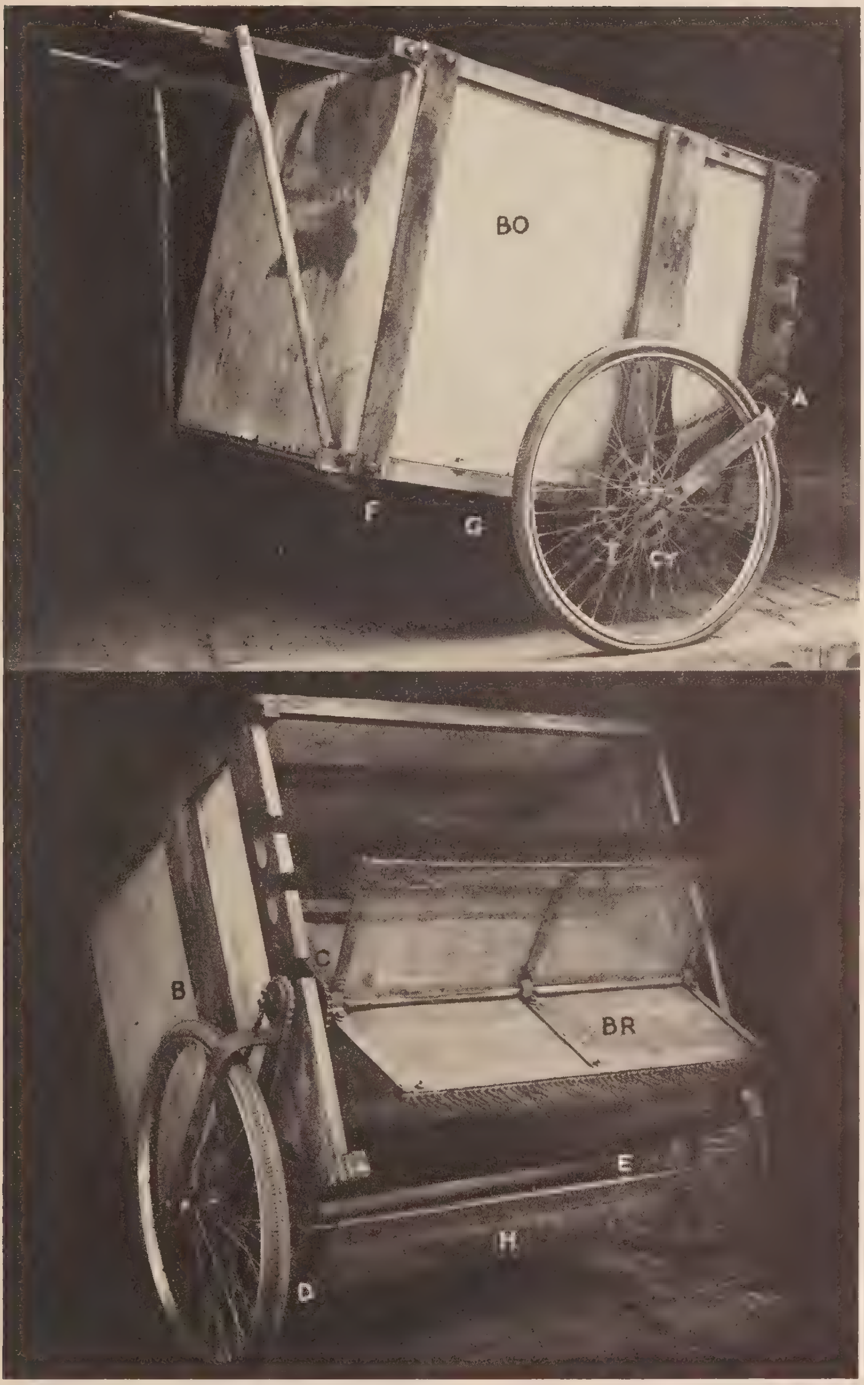

New Hopperdozer Machine.

BO, adjustable box ($2\frac{2}{3}' \times 3' \times 3\frac{1}{3}'$); BR, brushes; CY, cycle wheels (22″ diameter); A, flywheel; B, screw for fixing A to brushes; C, second flywheel; D, pulley permanently fixed to the right of the front roller E; F, second roller; G, canvas piece rolled by rollers E and F; H, container in which insects are trapped.

NOTES ON SOME COCCINELLIDAE (COL.) FROM ISLANDS IN THE INDIAN OCEAN.

By Desmond Vesey-Fitzgerald.

Rodolia chermesina, Muls.

This species is found on most of the islands of the Seychelles archipelago including the sand cays of the Amirantes group. It is said to have been introduced about sixty years ago to prey on the Coccid pest *Icerya seychellarum*, which is reported to have been the most serious pest of coconuts in the Colony at that time. The *Icerya* is the only prey of *R. chermesina*, and the latter has evidently kept the former in check on coconut but is unable to prevent occasional damage being done to fruit and other trees. The plants most frequently damaged by *Icerya* are :—Jak fruit, bread fruit, banana, avocado, citrus and forest tree seedlings, notably *Eucalyptus*, *Albizzia* and *Casuarina*. On certain islands where *Rodolia* is not present *Icerya* still occasionally damages coconut. *Vedalia cardinalis*, the famous predator of *Icerya purchasi*, also feeds on *Icerya seychellarum* in captivity, but, to date, liberations have failed to establish this species in Seychelles. Hence *R. chermesina* remains the most effective known predator of *I. seychellarum* under Seychelles conditions. No parasites are known from *R. chermesina* in Seychelles, but the black ant, *Technomyrmex albipes*, which constantly attends *Icerya* in large numbers, drives away the Coccinellid.

Life-history.

The egg.—Elongate oval, rather less than 1 mm. greatest length ; colour reddish orange. The chorion is evenly covered with regular fine impressions. The eggs are laid singly or in pairs, or in irregularly arranged groups of larger numbers. They usually lie on one side, and may be exposed on a leaf, hidden under the host, or placed inside empty skins ; or they may be actually laid on the body or in the waxen tail-tuft of the living *Icerya*. The egg hatches four days after oviposition. The newly hatched larva is very active, but the fourth-stage larva is sedentary and remains anchored amongst its prey by the suction-pad situated at the tip of the abdomen. The larva feeds by sucking the body-juices of its host. A large *Icerya* attacked by a small *Rodolia* larva may recover, the wound becoming closed by a yellow scab. The first change of skin takes place after 2–3 days, the second in a further 3–4 days and the third in another 2–3 days. The fourth-stage larva is of a dark purple colour, but the whole of the body, except the centre of the ventral surface of the abdomen, is thickly covered with a glaucus " bloom " so that the living larva appears greyish. Length 6·5 mm. The body is soft and obese, the back strongly arched. Dorsal prothoracic sclerites feebly chitinised, pigmented along their inner edges and together forming a flattish shield. The meso- and metathoracic sclerites are represented by lateral, flat, lightly pigmented and slightly chitinised, thumb-mark-shaped areas. On each side of the meso- and metathoracic segments are a pair of rather short finger-like tubercles. The dorsal tubercles of these segments are vestigial. On each of the first eight abdominal segments are six tubercules arranged in a paired median, lateral and an intermediate series. Those of the median and intermediate series are simply small knobs ; those of the lateral series are finger-like, becoming progressively shorter towards the tip of the abdomen. The ninth segment, which is the last one visible, is unarmed.

When the larva is full-fed it becomes quiescent. This prepupal stage lasts two to three days and then the larva changes into a pupa. The pupae occur scattered about over the food-plant of the prey, there is never any clustering of the larvae prior to pupation.

The pupa is pinkish coloured. This colour is actually located in the body of the insect within the pupa, since the perfect insect emerges from the pupa fully pigmented, while the actual skin of the pupa is of a semi-transparent dirty yellow colour. The pupa is enclosed in the grey larval skin, which splits down the centre of the back exposing the back of the pupa. The pupal period lasts one week.

The male and female are similar in appearance, they are ready to copulate within two days after emerging from the pupa. The first eggs are laid four days after the female has emerged from the pupa. The adult life lasts at least five to eight weeks. In the case of one pair kept under observation the male lived 35 days and the female 43 days. During a period of 16 days the female laid 150 eggs, the greatest number recorded for any one day being 28. A second pair survived captivity for 57 days, after which they were lost. During a 27 day period 311 eggs were laid, which gives an average of 11·5 a day. The greatest number actually noted for one day was 22.

Feeding Habits of Exochomus flavipes.

This species was last year introduced into the Seychelles proper, but it already occurred in some of the southern coral islands of the Aldabra Group. *E. flavipes*, Th., preys on soft scales and mealybugs, such as *Lecanium* spp., *Pulvinaria* spp., and species of *Pseudococcus*. In this connection it is worth recalling that in an earlier publication (Bull. Ent. Res., **29**, p. 186) it was forecasted that *E. flavipes* was a predator of this group on " colour pattern " grounds, although at that time the species had only been found associated with APHIDAE.

Under stress of circumstances this species shows particular aptitude for feeding and even breeding on a wide range of prey, and it seems likely that this habit has some bearing on its survival on small oceanic islands. *E. flavipes* was found to be abundant, for example, on Wizard Island, Cosmoledo, in 1937. This island is a narrow wind-swept strip of land situated on an atoll reef. Among the few trees present were several *Pisonia grandis*, which is a common host-plant of a Coccid, *Pulvinaria* sp. The *Exochomus* had lately been feeding on this scale but had apparently completely finished it up. At the time the island was visited, therefore, a fairly big population of adult beetles was present, but none of their normal host scales were in evidence. The beetles were, however, found feeding on an undetermined scale on *Tournefortia* and on *Chionaspis inday* on leaves of coconut. Both these scales belong to the subfamily DIASPIDINAE, a group normally neglected by *Exochomus*. No larvae were found associated in either case with these scales. Of greater interest was the fact that several of these beetles were attracted to light at night, and these began to feed on the corpses of numerous small Diptera which had fallen exhausted on a white table-cloth. This rather aberrant feeding habit has recently been encountered again in very different circumstances. At Tananarive, the capital of Madagascar, there is a small islet in the middle of an ornamental lake. A low hedge surrounds the islet and upon the foliage of this large number of CHIRONOMIDAE were resting during the daytime. Large numbers of both adult and larval *E. flavipes* were present on the hedge and both forms were taken feeding on the adult CHIRONOMIDAE. Moreover, a careful search failed to reveal any sign of COCCIDAE, so it is certain that the beetles were entirely dependent on this source of food and probably had been for some time past. The larva feeds by sucking-up the body juices of its prey. Thus if a gnat was crushed, the Coccinellid larva was content to drink the exuding juices and it did not consume the corpse.

THE SEARCH FOR PARASITES OF WHITE GRUBS (MELOLONTHIDS) IN ZANZIBAR, ALGERIA, MOROCCO AND FRANCE.

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(PLATES VII–X.) E.Y

1. Introduction.

In continuation of the work of parasite investigation, carried out by various officers of the Division of Entomology of the Department of Agriculture, Mauritius, with a view to furthering, in this Island, the control of the sugar-cane pest, *Phytalus smithi*, Arrow (Col., Melolonth.), the writer was detailed to proceed on a mission to Zanzibar, North Africa and some parts of France, to search in these countries for parasites of Melolonthids, with a view to their introduction into Mauritius.

The following account covers a period of investigation of sixteen months, from February 1938 to June 1939.

In Zanzibar the searches extended over two months and nine days, from 14th February to 25th April, 1938. It was intended in the first instance to explore this island with a view to obtaining some first-hand information on the status of the several Melolonthids reported to occur in the clove plantations.

In Algeria, the investigation covered a period of one month and twelve days from 25th May to 8th July, 1938. In view of the relatively few white grubs obtained there during the survey, and of their low degree of parasitism, the mission left for Morocco. In this country, the entomological survey extended over the period 9th July to 18th August, 1938. The discovery of an important centre, in the vicinity of Rabat, where white grubs occur indigenously over large forest areas, led to the finding of a parasitic Dexiid fly, *Dexiomorpha picta*, Meig.

Owing to the far advanced summer season in Morocco, the soil was very dry and hard to dig; white grubs were scarce and very deep in the soil; many of them were in the pre-pupal stage. In these circumstances, it was considered necessary to await the advent of the first showers, which generally occur in October. Between the middle of August and the end of September, the mission proceeded to France, in the region of Normandy, where heavy infestation of the common white grub, *Melolontha melolontha*, L., was reported to occur. After a thorough survey conducted in the regions of l'Isle de France and Oise, the writer returned to Morocco on 5th October 1938 and restarted his investigation in that country until the end of the mission on 15th June 1939.

In order to throw more light on the results of the surveys hereafter discussed, a general outline of the previous records of white grubs from the above-mentioned countries is considered necessary. As the genus *Phytalus* has many biological affinities to the genera *Rhizotrogus*, *Amphimallon*, *Geotrogus*, *Schizonycha* and *Entyposis*, the searches undertaken were entirely focussed on Melolonthids belonging to these genera.

In Zanzibar, K. W. von Dalla Torre (1912) recorded the following species of *Schizonycha* viz.: *S. sansibarica*, Kolbe, *S. rorida*, Gerst., *S. insulicola*, D. T. (=*cribrata*, Kolbe), *S. major*, Kolbe, *S. tumida*, Cast. A few miles off this Island, on the East African coast, at least forty species of *Schizonycha* are recorded.

In North Africa, only two species of *Schizonycha* are recorded, viz. : *S. algirica*, Fairm., and *S. dumonti*, Peyer. The genera *Rhizotrogus* and *Amphimallon* are mainly Palaearctic. In Winkler's "Coleopterorum Catalogus Regionis palaearcticae" (1924–32) at least 39 species of *Rhizotrogus* are recorded from Algeria, 13 from Morocco, and 10 from France.

The species of *Rhizotrogus* in Algeria recorded as being of economic importance are *R. amphytus*, Buq., *R. euphytus*, Buq., *R. vorax*, Mars., and *R. numidicus*, Luc. These species are pests of wheat and vines.

In Morocco, *Rhizotrogus sordescens*, Fairm., is the only species recorded as a sporadic pest of corn, wheat, beetroot and vines.

In France, many of the 10 species of *Rhizotrogus* are well known pests of market-gardens, forest nurseries and lawns.

The genus *Geotrogus* seems to be peculiar to North Africa ; it is very close to *Rhizotrogus*, from which it differs in that the membranous wings are wanting in the females and the sternum in both sexes is devoid of tufty hairs.

In Algeria nine species of *Geotrogus* are recorded ; of these *G. deserticola*, Blanch., is noted by Delassus as a pest of wheat in the uplands, and *G. inflatus*, Buq., is recorded by Rivière as a pest of wheat and corn in many localities. In Morocco, *Geotrogus olcesi*, Fairm., is a sporadic pest of wheat and vines in the Middle Atlas.

With regard to the genus *Amphimallon*, five species are recorded in Morocco by Winkler ; no economic damage by these insects has been reported in this country. In Algeria thirteen species are mentioned by Winkler, but no record on the status of these insects could be obtained. In France, there are eight species of *Amphimallon*, only one species (*A. majalis*, Raz.) being recorded by Regnier as a pest of lawns in the region of Rouen.

2. Survey in Zanzibar.

The status of white grubs in Zanzibar can be summarized as follows : (*a*) white grubs infesting the clove plantations, (*b*) white grubs on grass lands and various native food crops in the coastal belt.

Of the white grubs found in clove plantations, 90 per cent. were SERICINAE, most probably *Idaecamenta eugeniae*, Arrow. These larvae were found at the base of clove trees within a radius of 8–10 feet ; their number per tree varied from 0 to 60 (Plate VII, fig. 1). All the diggings tend to show that this species can hardly be considered as of any economic importance. Out of a total of 1,500 larvae of this type obtained from diggings in various parts of the Island, about 10 per cent. were of the third stage of development and 90 per cent. of the first and second stages. No endoparasite was found in them on dissection. Several cocoons of a Scoliid were found at 12–24 inches deep in the soil ; they were no doubt those of a *Tiphia* judging from their size and structure. The other white grubs found in the clove plantations belonged to *Schizonycha* and *Entyposis* ; they represent about 10 per cent. of the total larvae obtained in these regions. Adults of both types, viz., *Entyposis impressa*, Kolbe, and *Schizonycha* spp., were obtained during the diggings, and on night searches in the clove areas.

In the coastal belt region, four different types of Melolonthine larvae were obtained, nearly all being in the third stage of development. From some of these larvae the subsequent breedings yielded *Entyposis impressa*, Kolbe, and a Rutelid, *Anomala delagoa*, Pér. Most of these larvae were obtained either in grass lands or in food crops, mainly cassava, maize and banana. None of these plants suffered from the attacks of the white grubs. From the various diggings on the coastal belt, 4,554 larvae were obtained. Of these 2,241 represent larvae of *Entyposis* and *Schizonycha* ; 1,221 larvae of *Anomala delagoa*, Pér., and 1,092 larvae of

Anomala spp. On dissection of these larvae, a Dipterous endoparasite was found, a Dexiine fly, *Microphthalma disjunctum*, Wied.

The following table summarizes the results of the examination :—

TABLE I.

Type of larvae	No. of larvae examined	No. of larvae parasitised by *M. disjunctum*	Percent. parasitism	Stage of parasitised larvae
1. *Entyposis* and *Schizonycha* spp. ...	2,241	12	0·53	II
2. *Anomala delagoa*, Pér.	1,221	25	2·02	III, II
3. Other species of *Anomala* ...	1,092	2	0·10	II, III

Parasitised larvae were found soon after the start of the heavy rain in March. As many as three Dipterous larvae per host were found on dissection ; the tracheal funnel was found near the last thoracic segment or the posterior abdominal spiracles. Apart from *Microphthalma disjunctum*, several white grubs bearing larvae or eggs of Scoliids were found. In some cases the parasitism was of the typical *Campsomeris* type, *i.e.* the host completely paralysed and bearing eggs or larvae of the wasp on the ventral side of the abdomen. In other cases, signs of parasitism by a Tiphiid were noticed, the host larvae being very active and bearing eggs or larvae between the first and second and second and third thoracic segments. Unfortunately no adult wasp could be obtained from the pupae secured, but their general structure confirms the above assertion. The percentage of parasitism by Scoliids amounted to about 0·6 per cent. on 5,000 white grubs examined.

Of the other Scoliids captured, the following should be mentioned : *Campsomeris curvivittata*, Sauss., *C. mansuefacta*, Brad., *Scolia* (*Discolia*) *disparilis*, Kl., *Scolia* (*Discolia*) sp., and three other species of *Campsomeris* not yet determined.

Collection of adults started soon after the first shower of rain, at the end of March. From 26th March to 15th April, 1938, a total of 3,740 beetles were collected at night. The following table shows the results of the collection and examination :—

TABLE II.

Beetles	No. collected	No. parasitised	Percent. parasitism	Nature of parasite (Diptera)
Entyposis impressa Kolbe ...	3,581	36	1·00	*Pexopsis pyrrhaspis*, Villn.
Schizonycha sp. 1	25	2	8·00	*P. pyrrhaspis* & *Adapsilia* sp.
Schizonycha sp. 2	6	0	0	—
Camenta sp.	30	0	0	—
Anomala plebejus, Ol. ...	41	4	9·70	*P. pyrrhaspis*
Anomala tendinosa, Gerst. ...	20	0	0	—
Anomala plebejus Ol., var. *infuscata*, Ohs.	12	0	0	—
Anomala delagoa, Pér. ...	25	0	0	—

It follows from the above figures that the main larval parasite of white grubs in Zanzibar is *Microphthalma disjunctum*, Wied., which can find host material throughout the year. The same alternation of host occurs for the parasites of adult beetles.

3. Survey in Algeria.

The survey was conducted in the main centres where outbreaks of white grubs were reported in preceding years. One centre in the uplands, Berroughia, south of Algiers (900–1,200 metres altitude), was thoroughly surveyed with a view to obtaining information on the status of *Geotrogus deserticola*, Blanch., a species reported by Delassus as a pest of vines up-country. At a village, Brazza, seven kilometres from Berroughia, a severe outbreak of white grubs was found in various wheat fields. In a cultivated area of 615 hectares about 160 of these were found to be completely destroyed. The infestation occurred on patches of land to 2–5 hectares in area (Plate VIII, fig. 1); these were either isolated spots or contiguous ones forming very large areas where only bare soil was seen. It was very common to find as many as 30 *Geotrogus* larvae per square foot; the larvae were at 1–2 inches deep in wet clay soil or at 6–8 inches deep in drier soils. Depredations of white grubs in these regions generally start from February to April; adults are on the wing every three years in April–May. Of 11,281 larvae collected and examined from different spots, only 7 larvae (or 0·06 per cent.) were found parasitised by a Dexiid fly, *Microphthalma* sp. In one centre, out of 9,000 larvae examined 90 per cent. were attacked by the entomogenous fungus, *Metarrhizium anisopliae*, Sor. Over the whole area surveyed it was common to obtain two to three mummified larvae at each digging, thus showing the good natural distribution of the fungus in the upland country. The mean percentage of parasitism by *Metarrhizium* was 4·8.

Parasitism by Scoliid wasps was very scarce; of the 11,281 larvae examined only eight were found parasitised, *i.e.* 0·06 per cent. parasitism. In the fields the Scoliid wasp commonly found was *Campsomeris ciliata*, F.

The second survey was carried out in the department of Constantine at Guelma and its surroundings (280 metres altitude). In these regions 3 species of *Rhizotrogus* have been reported as pests on wheat, viz.: *R. amphytus*, Buq., *R. euphytus*, Buq. and *R. stupidus*, Fairm.

At the time of survey there, the digging was very difficult owing to the dryness of the soil; larvae were found only at a depth of 3–4 feet. Only 1,225 larvae were obtained for examination, of which 5 were parasitised by a Scoliid wasp; no endoparasite was found on dissection. It was reported that severe attacks of white grubs generally occur in the vicinity of Guelma every 2–3 years from December to March. Previous to the time of this survey, adults were reported on the wing in March 1938.

The reduction of the crop is reckoned at 70–90 per cent. in heavily infested wheat fields, the mean number of larvae per square yard being 50. In the infested fields the only parasite collected was *Campsomeris ciliata*, F. Other Scoliids collected in vegetable gardens were *Scolia* (*Triscolia*) *bidens*, L., *S.* (*Discolia*) *interstincta*, Kl., and a few males of *Myzine* spp.

The last survey was done in some places in the Sahel and Tell, where *Rhizotrogus numidicus*, L., had been reported as a pest of wheat and vines. At Bouira, 132 km. from Algiers, emergence of adult beetles was reported to have taken place in March–April 1938.

As a result of some diggings and ploughing at this place 2,750 larvae were collected and examined, all in the first stage of development; in only two larvae was a Dipterous parasite found. In the Western region, viz.: Miliana, Orleanville, Malakoff, Charron and Relizane, no white grubs were collected, for owing to the dry and hard state of the soil no digging could be done. These places were reported to be infested with the following *Rhizotrogus* : *R. vorax*, Mars., *R. numidicus*, Luc., and *R. stupidus*, Fairm. With regard to methods of control employed in these regions, the only one is the systematic use of ploughs in infested soils ; no great success has been achieved by the artificial inoculation of the soil with entomogenous fungi.

4. Survey in France.

During the few weeks spent in France, several surveys were made in the regions of Rouen, Beauvais, Compiègne, Rambouillet and Versailles. At La Feuillée, a village 45 km. from Rouen, large areas under pasture were found infested with the common white grub, *Melolontha melolontha*, L.

The degree of infestation ranged between 500–800 thousands of larvae per hectare. About 10,000 larvae were collected whilst an infested area was ploughed ; these were examined and dissected, but no parasite was found. From the same spot 74 larvae of *Anoxia* sp. and 51 of *Rhizotrogus* sp. were also examined ; the parasitism was nil. Thousands of the insectivorous crow, *Trypanocorax frugilegus*, L., were noticed in the infested pastures ; these birds were found picking out white grubs which were 2–4 inches deep in the soil. The appearance of infested pastures attended by crows is shown on Plate VII, fig. 2. As a control measure, the ploughing of the land followed by hand-picking of larvae was still in use.

In the town of Rouen, left bank, in a lawn, recorded three years ago by Regnier to be heavily infested with white grubs, re-infestation was reported this year. On digging a small patch of the infested lawn, 80,000 larvae per hectare were found. The larvae were, as previously recorded by Regnier, of the following species : *Amphimallon solstitialis*, L., *A. majalis*, Raz., and *Rhizotrogus aestivus*, Ol. About 5,000 of them were dissected, but no parasitism was found. From Rouen to Compiègne, several halts were made to enquire as to the occurrence of white grubs ; no severe infestation was reported.

This same state of affairs was noticed in a large beetroot plantation where the infestation was between 800–1,000 larvae per hectare. At Compiègne, Rambouillet and Versailles, several searches were made in lawns, but no larvae were obtained at the time of the survey. In some of these places, sporadic attacks on lawns have been reported in preceding years.

In the southern parts of France, a small survey was made in the vineyards of Arles and Avignon ; no severe infestation was reported. A limiting factor to the white grubs infestation in these places is the flooding of the land which occurs during 40–50 days each year.

5. Survey in Morocco.

Amongst the insect pests in Morocco, white grubs can be regarded as of minor importance. Two species are recorded as occasional pests of vines and wheat, viz. : *Rhizotrogus sordescens*, F., and *Geotrogus olcesi*, Fairm. ; their attacks are more localised in the interior than in the coastal belt.

At the time of the survey, no sporadic outbreak was reported ; larvae of the two above-mentioned species were very difficult to collect, even in places where damage had been reported 2–3 years ago.

In view of the scarcity of white grubs in cultivated lands, searches were then conducted in the coastal and sub-coastal cork-oak forest area (*Quercus suber*, L.), where many indigenous species of Melolonthids might possibly be found. Diggings were thus started in the Zaers and Mamora forests inland from Rabat. As expected, four different types of Scarabeid larvae were collected. From these two Melolonthines were bred, *Rhizotrogus carduorum*, Er., and *Amphimallon semivillosus*, Fairm., the remaining larvae being of the *Phyllognathus* and *Anoxia* types.

The following table shows the proportions of the various types of larvae collected in Zaers and Mamora forests in August 1938 :—

TABLE III.

No. of larvae examined	*Amphimallon semivillosus,* Fairm.	*Rhizotrogus carduorum,* Er.	*Anoxia* sp.	*Phyllognathus*
10,500	52%	25%	21%	2%
Instars of larvae	I & II	II & III	II & III	III

These were found in numbers varying from 10 to 60 at the base of cork oak trees and of various wild herbaceous plants which form the indigenous flora of the forest. Amongst these plants the following are worth mentioning : *Thymelaea lythroides, Daphne gnidium, Chamaerops humilis, Cistus salvifolius, Cistus monspeliensis, Cytisus linifolius, Asphodelus microcarpus, Lavendula stoechas,* and *Ulex spectabilis.*

During the months of July and August, the white grubs were very deep in the soil, at 18–36 inches, this being the aestivation period (Plate VIII, fig. 2). They reappear in the top soil, at 4–6 inches, soon after the beginning of the first showers in October–November and feed readily on the roots of numerous weeds and grasses which form the undergrowth peculiar to the cork-oak forests of Morocco.

Adults of *Rhizotrogus carduorum,* Er., started to be on the wing in October–November 1938 ; they were found generally in copulation soon after sunset. As many as 50 beetles could be collected on the shrub, *Thymelaea lythroides,* a plant which appears particularly attractive to them (Plate IX, fig. 1). They were on the wing from December 1938 to April 1939, the peak of emergence being in March–April. It should be noted that the adults were never collected on cork-oak trees.

In April–May 1939, adults of *Amphimallon semivillosus,* Fairm., started emerging. Unlike *R. carduorum,* they were on the wing in the evening, between 4 and 5 p.m. ; their flight is very swift and they are collected with great difficulty. This species has a wide range ; adults were obtained in the cork-oak forests, in various maize plantations surrounding Rabat, on vines, in citrus plantations and in flower gardens. A small severe infestation was reported in a vineyard at ½ km. from the M'Krenza forests of Zaers, where numerous larvae were collected during the survey.

A mean of 4–10 larvae per vine plant was recorded, but the damage was of no great economic importance. From the results of the survey, it appears that *Rhizotrogus carduorum* and *Amphimallon semivillosus* are the two Melolonthids specially confined to the sub-coastal and coastal belt of the cork-oak forests, the soil in these regions being of the light sandy texture known as *R'Mel.* On the other hand, *Geotrogus* larvae were mainly found in the heavy clay soil known as *Hamri* or *Tirs,* and seldom on light sandy soil.

From an economic point of view, it can hardly be said that *Rhizotrogus carduorum* and *Amphimallon semivillosus* cause any serious damage to cultivated plants in the areas surveyed. The cork-oak forests, where the larvae were found abundantly, show a very luxuriant vegetation in spite of the presence of 4–50 white grubs at the base of some of the trees.

6. Collection and Shipment of Dexiomorpha picta to Mauritius.

Soon after the discovery of the first parasitised grubs from the Zaers and Mamora forests in July–August 1938, a buying centre of white grubs was established in M'Krenza, 10 km. south of Rabat. Gangs of men, varying from 40–60 a day,

TABLE IV.

Shipment No.	1	2	3	4	5	6	7	8	9	10	Totals
Date of shipment from Casablanca	4.viii.38	19.ix.38	7.xi.38	7.xii.38	18.i.39	17.ii.39	21.iii.39	20.iv.39	31.v.39	17.vi.39	—
Date of arrival at Mauritius	9.ix.38	27.x.38	19.xii.38	17.i.39	21.ii.39	30.iii.39	3.v.39	7.vi.39	10.vii.39	22.vii.39	—
No. of live larvae sent ...	136	55	409	591	1,043	2,313	1,378	1,351	137	316	7,729
No. of larvae received alive in Mauritius	78	28	159†	476	889	1,607	709	582	0*	169	4,697
Percentage survival	57·9	50	38·8	80·6	85·2	69·4	51·2	49·4	0	53·2	60·66
No. of puparia obtained ...	38	18	47	148	301	746	283	392	0	289	2,262
No. of adult flies obtained ...	21	7	31	103	196	623	174	134	0	42	1,331
Percentage of adults emerged	15·5	12·9	7·5	20·7	18·8	26·9	12·5	9·9	0	13·2	17·11

* Consignment completely lost, owing to not having been placed in cool chamber on board.
† Consignment partly lost, owing to not having been placed in cool chamber on board.

were engaged on the digging of larvae, which were bought from them at a rate varying from 15 to 35 centimes per larva. The area of the cork-oak forest of M'Krenza is about 3,550 hectares ; of these, over 1,500 hectares were thoroughly dug during the 12 months of the survey.

The number of live larvae examined during the period July 1938 to June 1939 amounted to 561,000, as shown in Table VI. Every day all the larvae were transported to the laboratory of La Défense des Végétaux, Rabat, in large biscuit tins and examined. All parasitised larvae were sorted out and placed singly in ointment tins of 45 × 30 mm., with moistened peat of about 50–60 per cent. humidity. These tins were subsequently placed in a refrigerator room at 4–6°C. until their packing for shipment to Mauritius. Shipments were made every 25–35 days. Each tin was wrapped in well damped moss and packed in wooden cases of 16 in. × 16 in. × 8 in. It was found that the peat in the tins should not be overdamped, otherwise the percentage of mortality reaches a very high figure. From the collecting day to the date of despatch from Rabat, at least 16–20 per cent. of the parasitised larvae died ; this being due mostly to mechanical shock, either in the course of the digging or during their manipulation by the labourers in the field and during their transport from the forest to the laboratory. The shipments during transit from Rabat to Mauritius were placed on board in the fruit chamber at 4–6°C. The maximum number of days during which the parasitised larvae were exposed to this temperature from the date of collection in Morocco to the date of reception in Mauritius was 70 days.

Table IV summarizes the results of the various shipments to Mauritius.

7. **Bionomics and Morphology of Dexiomorpha picta, Meig., in Morocco.**

This Dexiine fly (Plate X) is distributed over Central and Southern Europe, and is recorded now for the first time in Morocco, where it has a wide range of hosts. An examination of field-collected grubs from the Zaers and Mamora forests (Plate IX, fig. 2) in July–August 1938 gave the following data :—

TABLE V.

Hosts	Larval stage	No. of larvae examined	Percentage parasitism
Amphimallon semivillosus, Fairm. ...	I & II	1,850	1·8
Rhizotrogus carduorum, Er.	III	950	1·3
Anoxia sp.	II	820	1·0

Parasitism on *Rhizotrogus carduorum* and *Anoxia* larvae was found until the month of October, when the larvae suddenly disappeared, having transformed into pupae and adult beetles. From October to May the incidence of the parasitism is on second and third stage larvae of *A. semivillosus*, which transform into pupae and adults in May–June. Table VI shows the relative incidence of parasitism by *D. picta* during the course of the investigation from July 1938 to June 1939.

The counting of parasitised grubs was based on the funnels visible through the derm. The percentage of parasitism is in fact higher if it is considered that signs of parasitism can only be detected by the tracheal funnels, which are only visible when the larva of the parasite fly is at its second stage of development in the host. On the other hand, during the daily examination of larvae collected from different spots in the same area, it was found that parasitised grubs are found in patches instead of being uniformly distributed over the infested zone. Isolated diggings and examination tend to show that the percentage of parasitism as generally worked out is very

TABLE VI.

Months	No. of larvae examined	No. of larvae parasitised	Percentage parasitism
1938 July	6,000	78	1·30
August	14,000	160	1·14
September	4,000	16	0·40
October	28,000	345	1·23
November	38,000	676	1·70
December	58,000	1,003	1·72
1939 January	70,000	1,878	2·68
February	100,000	1,557	1·55
March	104,000	1,471	1·41
April	66,000	866	1·31
May	48,000	260	0·69
June	25,000	280	0·95
Total ...	561,000	8,590	(Mean%) 1·5

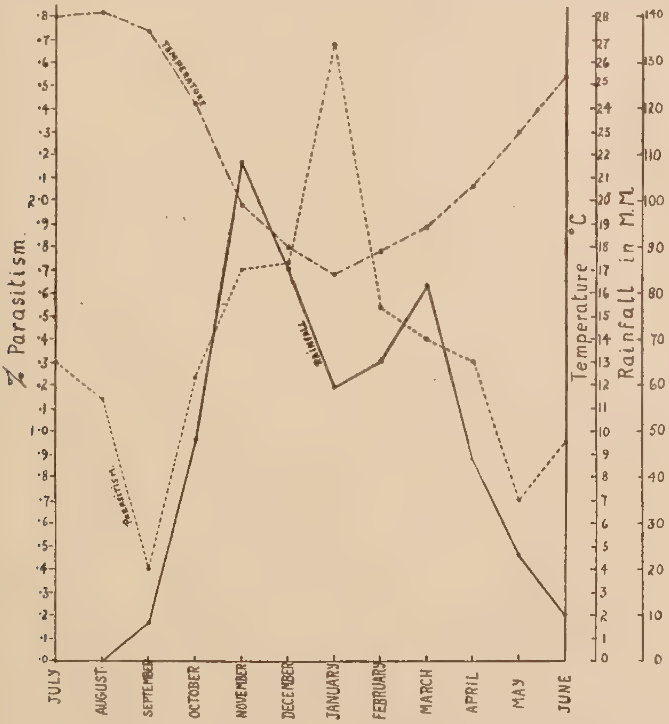

Fig. 1. Monthly incidence of parasitism by *Dexiomorpha picta*, Meig., in relation to temperature and rainfall at M'Krenza (Zaers).

erroneous. For instance, if the percentage of parasitism is calculated for separate diggings in the same area, as much as 16 per cent. parasitism could be found in 400–500 grubs examined, whilst in the remaining diggings, at a few yards intervals, the percentage of parasitism varied from 0 to 1 per cent. on an average of 3,000 larvae.

Text-fig. 1 shows a graph illustrating the monthly percentage of parasitism during one year's observation, in relation to the rainfall and temperature chart at Rabat, a few kilometres from the M'Krenza forest, the place where nearly all the searches for white grubs were made during the year. It results therefrom that the parasitism reaches its peak in January, when the temperature is at its lowest level and the soil abundantly soaked with the first rain occurring in November–December. It is also at this time that the grubs are very near the top soil (2–4 inches). During the month of September the parasitism is at its lowest point, and this corresponds with the period when the grubs are found deep in the dry soil, and not easily found by young larvae of *Dexiomorpha*.

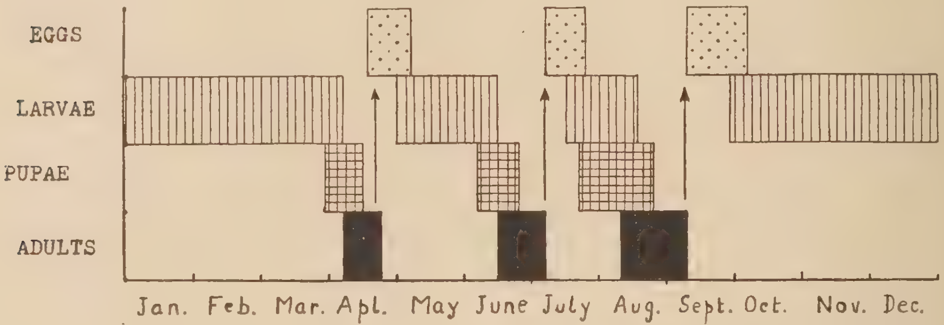

Fig. 2. Diagrammatic calendar of the life-cycle of *Dexiomorpha picta*, Meig., from field and laboratory data.

Text-fig. 2 shows the diagrammatic calendar of the life-cycle of *Dexiomorpha picta*, Meig., as obtained from laboratory breedings and field observations. This fly has three generations yearly in Morocco ; the first brood starts in March–April, when the first flies are found in the fields. From mid-April to mid-June, the life-cycle of the fly is completed in about 75 days (imago to imago).

The second generation starts from June–July to September, the period at which the latest larvae before aestivation are parasitised in July. The third generation starts from September to March–April of the next year, the parasite remaining dormant in its host during the winter for about 160–180 days. The data in Table VII recapitulate the biology of the fly.

Adult flies are generally found in the field in dull weather at dawn. Males are on the wing 30 minutes to one hour before the females. Copulation in the field has been observed in the morning, on the soil. It is very common to notice a greater number of males than females ; in several captures as many as 80 males have been collected as compared with 10 females. Males generally hatch 4–6 days before females, and their size is generally much greater than that of females. Numerous adult flies were found feeding on the secretion of the scale *Lecanodiaspis cardoa*, Targ., common on the shrub *Cistus salvifolius* in the forest. After 11 o'clock it is very rare to find *D. picta* in the field. Copulation generally starts 12–24 hours after emergence of the females, and these are gravid 12–15 days later.

Eggs incubate in the ovarian sac, and as many as 80 planidia hatch at a time. The total number of young larvae laid per female is 300–350. In the uterus, the eggs are white in colour, and turn to pale straw before hatching ; they are sabre-like, curved, tapering at one end, and measure 1·2 mm.–1·5 mm. in length and 0·2 mm.–0·3 mm. in breadth (fig. 5, *d*).

The young larva is very active as soon as hatched and starts to penetrate the derm of its host with its mouth-hooks. Penetration is effected in 30 minutes to

TABLE VII.

Adult flies hatched and found in fields	First generation	Second generation	Third generation
	March–April	June–July	Sept.–Oct.
No of days for maturing of larvae before extrusion by female fly	13	15	15
Mean no. of days for parasite in host larva	35	40	160
Pre-pupation period : larvae outside host, in soil	4	3	6
Pupation period	20	20	35
Total number of days	72	78	216

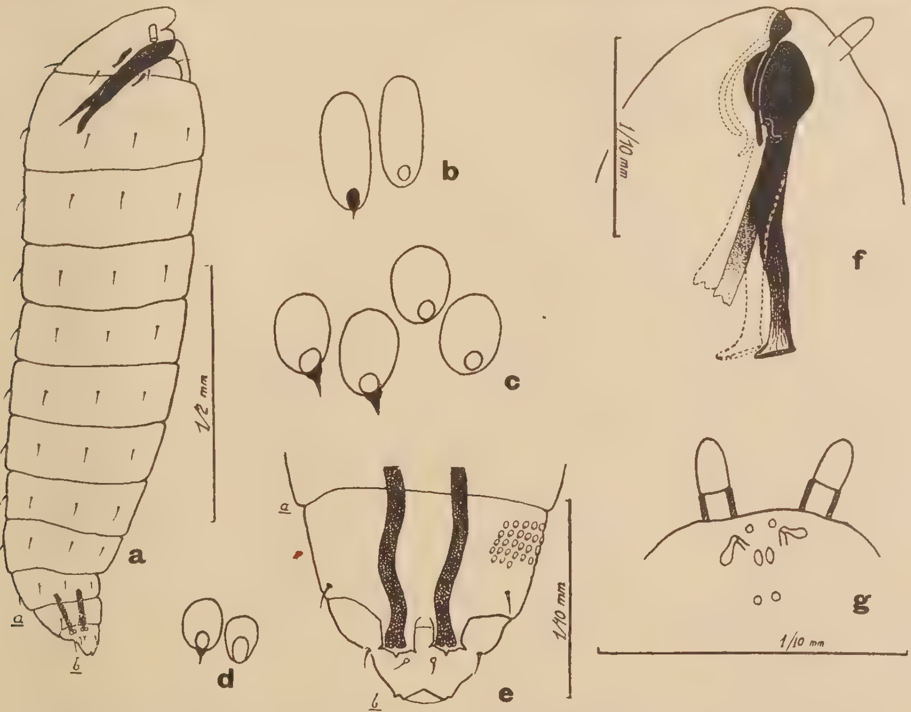

Fig. 3. *Dexiomorpha picta*, Meig. : **a**, first instar larva (setae are represented slightly longer) ; **b, c, d,** different forms of scale-like structure on derm (fore, mid and hind parts of larva) ; **e,** posterior segments enlarged—scale-like structure represented only on a small portion of segment ; **f,** details of mouth-parts enlarged ; **g,** head enlarged, showing antennae, palp, etc.

2 hours in any part of the body of the grub. The first stage larvae measure 1·1 mm.–1·4 mm. in length and 0·25 mm. 0·26 mm. in breadth ; they are pale straw in colour. The pharyngeal plates and antennae are as figured (fig. 3, *a*, *f*, *g*).

Each body segment bears regular rows of bristles close together. Under high power magnification the derm of the various segments is covered with a series of scale-like structures, each bearing a very short stout spine, which differ in form on the anterior, median and posterior segments (fig. 3, *b*, *c*, *d*). The last segment bears 4 caudal setae ; the tracheal system ends in two parallel tubes which terminate in the posterior spiracles (fig. 3, *e*). The first-stage larvae live apparently free in the host's body, showing no connection for respiratory purposes with the tracheal system or through the derm. It is only 12–15 days after penetration that the parasite larva moults to its second stage ; the host grub then shows external signs of being parasitised, the tracheal funnel becoming visible through the derm as brown or pinkish dots, which are seldom found near the first posterior spiracles, and more commonly near the last abdominal spiracle (Plate X, fig. 1). As many as five first-stage larvae were found in field-collected grubs, but only a single individual reaches maturity in each host. As in other Dexiid larvae, feeding occurs during the early stages upon the fluid contents of the host's body, and at later stages upon the fat-bodies of the vital organs. The third-stage larva (fig. 4, *a*) is creamy white in colour and measures 10–14 mm. in length and 4–5 mm. at its broadest part. The body is divided into 12 segments, the last one bearing the posterior spiracles sunk in a groove. The whole body is enveloped in a fine sheath. At the posterior part, this sheath is slightly chitinised and forms the tracheal funnel which is always attached to the derm of the host. The posterior and thoracic spiracles, mouth-parts, pharyngeal plates are as figured (fig. 5, *a*, *b*, *c* and fig. 4, *b*). Fully developed larvae leave the host (Plate X, fig. 2) before pupation. The prepupal stage varies from 4 to 13 days according to the soil temperature. The second and third stages last 20–22 days in each summer generation and 140–145 days in the winter.

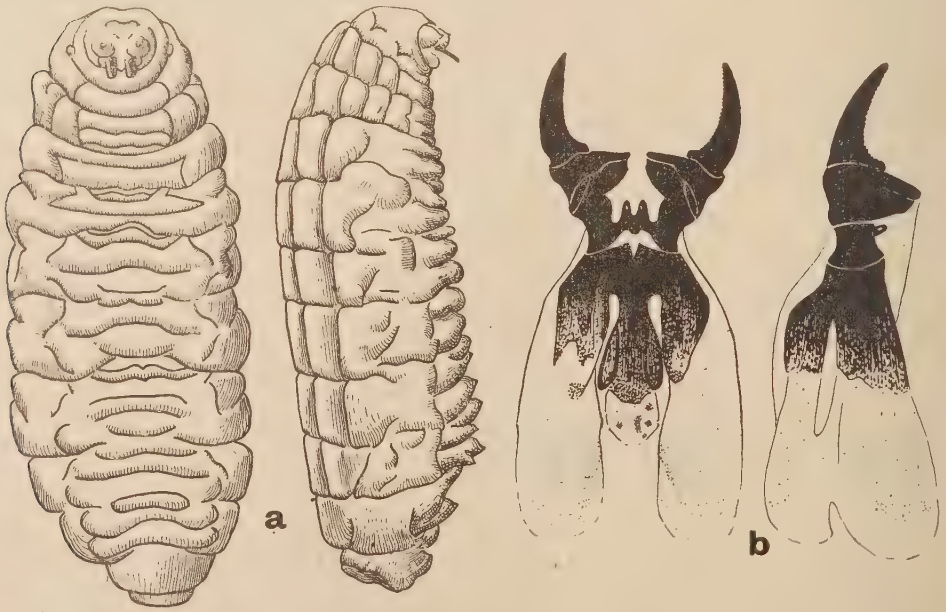

Fig. 4. *Dexiomorpha picta*, Meig. : **a,** third stage larva (× about 9) ; **b,** mouth-parts of third instar larva (× about 37). Dorsal and profile views.

The puparium (Plate X, fig. 4) is oblong and measures 7·5–11·0 mm. in length and 2·5–3·0 mm. in breadth ; its surface is coarse, dark brown and with a slight dull reflection. The anterior or thoracic spiracles are elevated and 5–7 branched. Pupal period in summer 14–20 days and in winter 30–77 days.

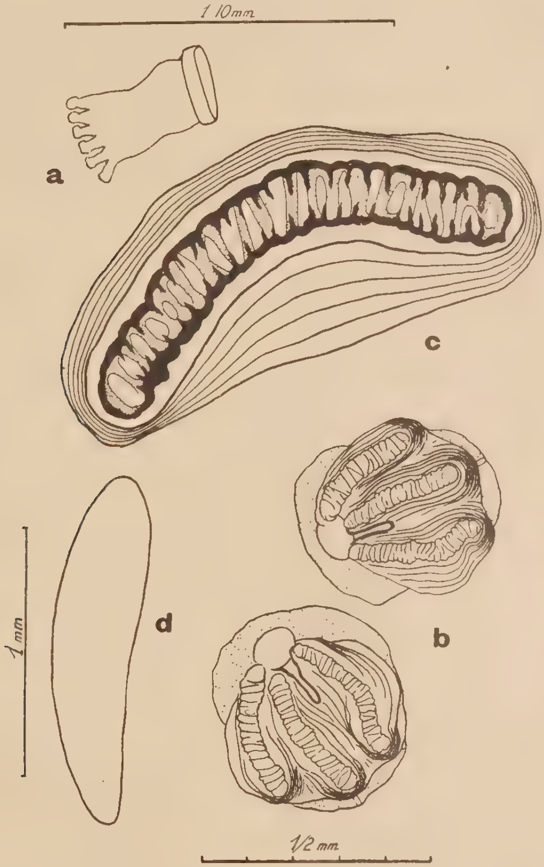

Fig. 5. *Dexiomorpha picta,* Meig. ; **a,** anterior spiracle of third instar larva ; **b,** posterior spiracle of third instar ; **c,** enlarged portion of one eyelet of **b** ; **d,** egg.

8. Other Enemies of White Grubs in Morocco.

In addition to *Dexiomorpha picta,* Meig., the following enemies and diseases of white grubs were found during the course of the survey :—

(*a*). A Tachinid parasitising adults of *Rhizotrogus carduorum.*

(*b*). Various Scoliids (*Tiphia, Campsomeris* and *Scolia*) attacking the larvae.

(*c*). Entomogenous fungi : *Metarrhizium anisopliae, Beauveria bassiana,* and *B. densa,* on larvae of *R. carduorum* and *A. semivillosus.*

(*d*). Insectivorous birds.

(*e*). Bacterial diseases and parasitic worms.

Among 93,000 adults of *Rhizotrogus carduorum* captured in the Zaers forest during the period December 1938 to April 1939, only 30 parasitised individuals were obtained. The percentage of parasitism was insignificant. Each beetle contained one parasite larva. The larvae and puparia obtained are of typical Dexiid type. No adult flies have as yet emerged, all the puparia being still alive after 5 months.

During the months of May and June, emergence of the beetle *Amphimallon semivillosus* occurred in fairly large numbers. In the field at 5 p.m. it was very often observed that this beetle was chased by various large robberflies, common in Morocco, the most important being *Selidopogon diadema*, F.

The other effective parasite of white grubs in the Mamora and Zaers forest was the Scoliid wasp, *Tiphia morio*, F., which was very common in the winter, being abundant in January–February. As many as 30 per cent. of the grubs collected in December in the Zaers forest were parasitised. The female wasp deposits its egg on the ventral side of the grub, between the 4th and 5th abdominal segments. There were several cases of superparasitism by *Dexiomorpha* and *Tiphia morio*. In December, 25 per cent. of the grubs parasitised by *Dexiomorpha* were superparasitised by *T. morio* ; the latter species in most cases completing its larval development more quickly than the endo-parasite.

Females of this species of *Tiphia* have very short wings and can hardly fly ; they feed on various wild flowers in the forest. Some 2,800 females were shipped to Mauritius in February–April, but owing to the long course of the voyage, no living insects were received in Mauritius.

Of the other Scoliids collected during the survey the following are worth recording : *Campsomeris thoracica*, Klug, *Campsomeris ciliata*, F.; *Myzine latifasciata*, Palma, *Scolia* (*Discolia*) *insubrica*, Rossi, *S.* (*Triscolia*) *bidens*, L., *S. varicolor*, Lucas, and 3 *Tiphia* spp.

With the advent of winter in November–December, a few mummified larvae were found attacked by the following entomogenous fungi : *Metarrhizium anisopliae*, *Beauveria bassiana* and *B. densa*. A few adults were found attacked by *Beauveria densa*.

Of the other natural enemies of white grubs in Morocco, the cattle egret, *Bubulcus ibis*, L., and the white stork, *Ciconia ciconia*, L., play an important rôle. These insectivorous birds are found in very great numbers following the ploughs and picking up all the grubs in the furrows. The blackbird, *Turdus merula mauritania*, L., was often noticed preying on white grubs.

9. Summary and Conclusions.

(1) An extensive survey covering a period of 18 months was carried out in Zanzibar, Algeria, Morocco and some parts of France with a view to obtaining parasites of white grubs for furthering the control of *Phytalus smithi*, Arrow, in Mauritius.

(2) In Zanzibar the results of the survey showed that white grubs are of no great economic importance in clove plantations in this Island. Larvae of several species of white grubs were obtained, viz. : *Entyposis impressa*, Kolbe, *Schizonycha* spp., *Anomala delagoa*, Pér., etc. ; these larvae are parasitised by the Dexiid fly, *Microphthalma disjunctum*, Wied. The percentage of parasitism at the time of the survey was from 0·10 to 0·53 per cent. Scoliids were not in great number ; the parasitism amounted to 0·6 per cent. Parasites of adult beetles were obtained on the following insects : *Entyposis impressa*, Kolbe, *Schizonycha* spp. and *Anomala plebejus*, Ol., the parasites being *Pexopsis pyrrhaspis*, Villen., and an *Adapsilia*, not yet determined. The parasitism on the above mentioned beetles varied from 1 to 9·7 per cent.

(3) In Algeria, amongst the most important white grubs are *Geotrogus deserticola*, Blanch., *Rhizotrogus euphytus*, Buq., *R. amphytus*, Bug., *R. stupidus*, Fairm., and *R. numidicus*, Luc. In a heavily infested centre in 12,000 larvae of *G. deserticola* examined the parasitism was only 0·06 per cent., the parasite being a *Microphthalma* sp. Entomogenous fungi were here well distributed, the percentage of larvae attacked by *Metarrhizium anisopliae* being 4·8. Parasitism of larvae by Dexiids in other areas was nil or very slight (0·06 per cent.). Amongst the Scoliids found in the various infested centres, the commonest was *Campsomeris ciliata*, F. No effective means of control against white grubs were obtained from this part of North Africa.

(4) In France, in large pastures in the region of Rouen, the commonest species was *Melolontha melolontha*, L., the infestation ranging between 500,000 and 800,000 larvae per hectare. Over 5,000 larvae from this region were dissected, but no endo- or ectoparasite was found. One lawn in Rouen was severely infested with larvae of *Amphimallon solstitialis*, L., and *A. majalis*, Raz. ; no endoparasite was found in 5,000 larvae examined. In the region of Arles and Avignon it was reported that white grubs in some areas are kept under control by periodic flooding of the vineyards, which occurs during 40–50 days each year.

(5) In Morocco, four species of Melolonthid larvae were found in the cork-oak forests : 50 per cent. *Amphimallon semivillosus*, Fairm., 25 per cent., *Rhizotrogus carduorum*, Er., 21 per cent. *Anoxia* sp., and 2 per cent. *Phyllognathus* sp. Of a total of 561,000 larvae examined, the mean parasitism by *Dexiomorpha picta*, Meig., amounted to 1·5 per cent., but parasitism is very often local and in small areas may amount to as much as 16 per cent. The relation between the degree of parasitism and the rainfall and temperature is shown graphically.

(6) The bionomics of the parasite *Dexiomorpha picta* in Morocco are fully discussed, and the morphology of the various stages is described. The rôle of other parasites and predators of the larvae and adult beetles is considered.

(7) An account of the methods of packing and shipping *Dexiomorpha* to Mauritius is given. The larvae were kept in cool storage at 4–6°C., and the survival rate was from 49 to 80 per cent. The percentage of flies emerging from the total number of parasitised larvae sent ranged from 10 to 26·9.

(8) The results of the North African parasite work indicate that *Dexiomorpha picta*, Meig., is the only Tachinid which is worthy of further attention. It is very desirable to continue the importation of this species so that a large number of individuals can be made available for release in Mauritius. Improvements in the technique of reception and breeding have been made, and in view of the wide host range, the fly may be said to be the most promising larval parasite yet discovered.

(9) Of the Scoliids, it would appear that *Tiphia* larvae cannot survive the long journey to Mauritius, but in the future, attempts may well be made to ship pupae. The species of *Campsomeris* do not appear to be of any importance, and little time should be spent upon them.

10. Acknowledgments.

The writer wishes to tender his thanks to the various Government officers of the Entomological, Agricultural and Forestry Services, in the various countries mentioned where he has had to work. Special thanks are due to all members of the Défense des Végétaux in Morocco, where the greatest part of the mission was spent. The services rendered by the Entomologist, Mr. Charles Rungs, and the Plant Inspector, Mr. Pierre Brémond, were most valuable.

Some of the photographs are due to the kind assistance of the Plant Inspector, Mr. L. Lespès, Port Lyautey.

In the various regions of Zanzibar, Algeria, Morocco and France, the writer was granted all facilities to work in official laboratories, where ready assistance was always given him. This unceasing help greatly facilitated his work. Last, yet not the least, the writer is much indebted to Dr. W. F. Jepson, Government Entomologist, Mauritius, for his ever ready advice and for the reading of this manuscript. The writer is also much indebted to Dr. J. Villeneuve de Janti, Rambouillet, for the prompt identification of the Tachinids submitted to him and to the Imperial Institute of Entomology for the determination of the other insects mentioned in the text.

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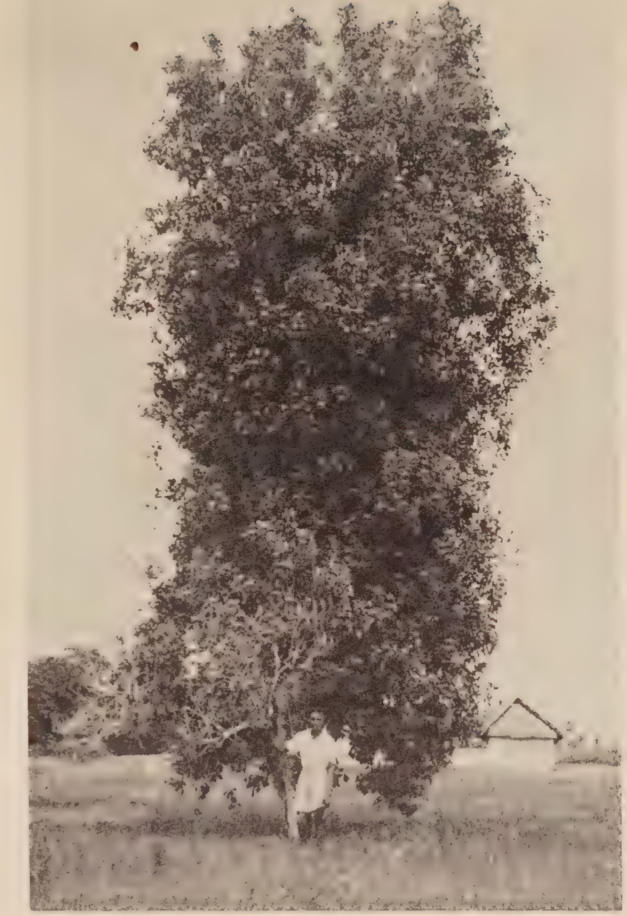

Fig. 1. Clove tree at the base of which 50-60 white grubs were found (Zanzibar).

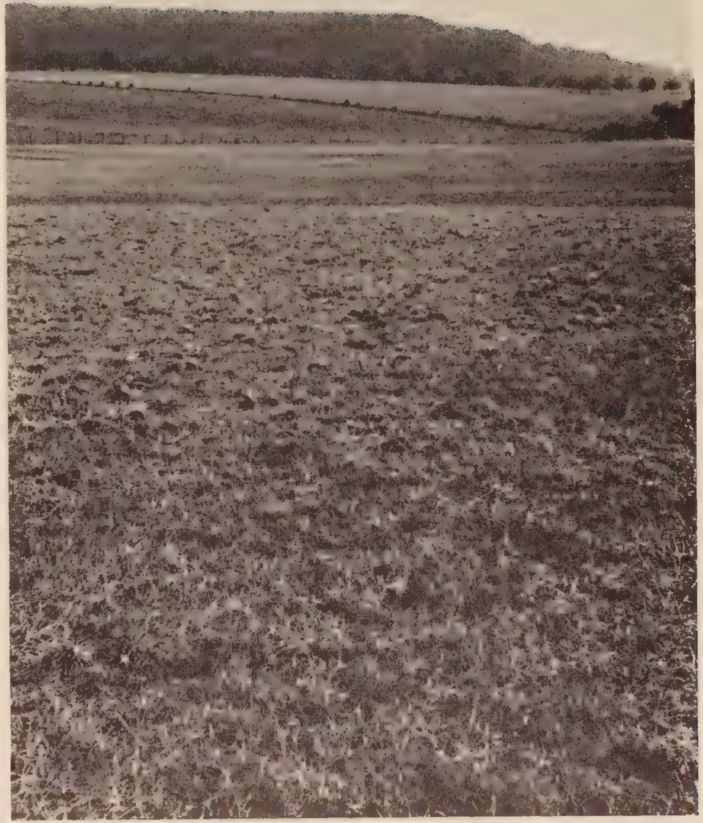

Fig. 2. Meadows heavily infested with white grubs *M. vulgaris*, L., at La Feuillée near Rouen, France. Note the aspect of the field—dark spots represent digging or picking done by the crow (*Trypanocorax frugilegus*, L.).

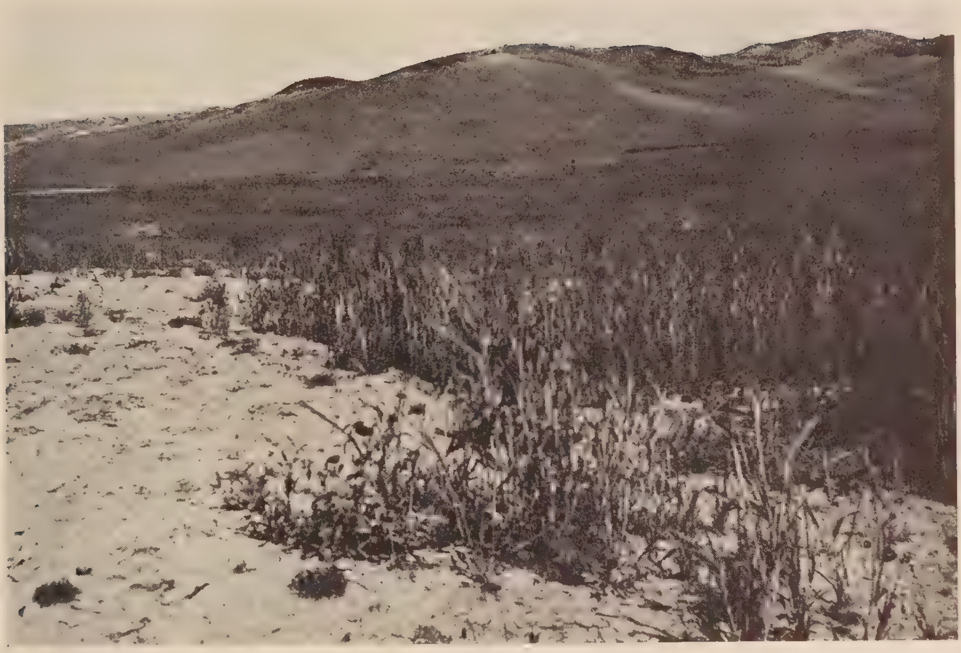

Fig. 1. Field of wheat heavily infested with white grubs in the up-country of Algeria (Brazza).

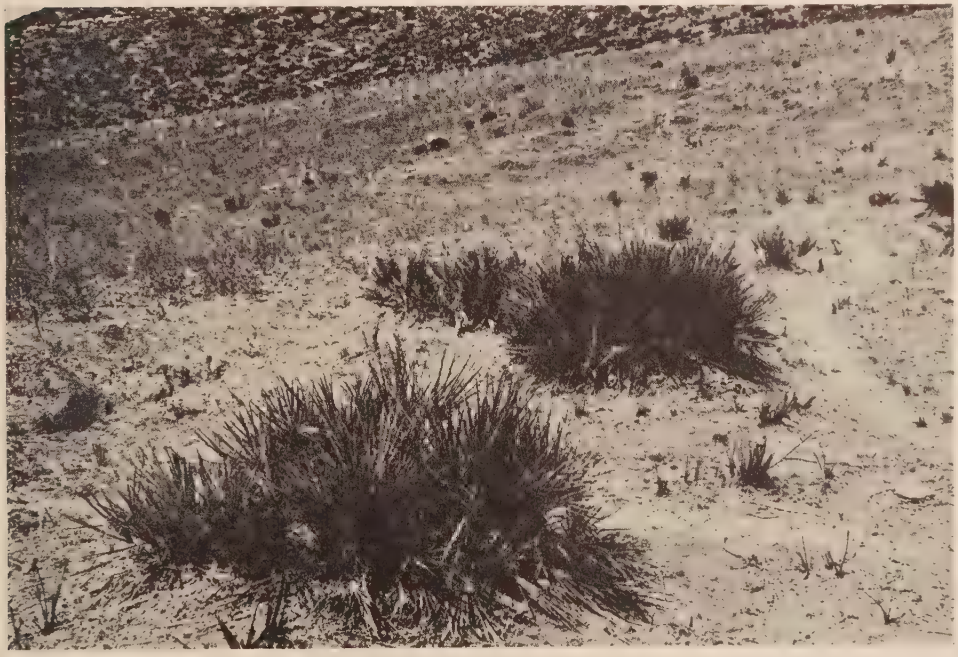

Fig. 2. The dwarf palm (*Chamaerops humilis*, L.) at the base of which white grubs are found in summer (Morocco).

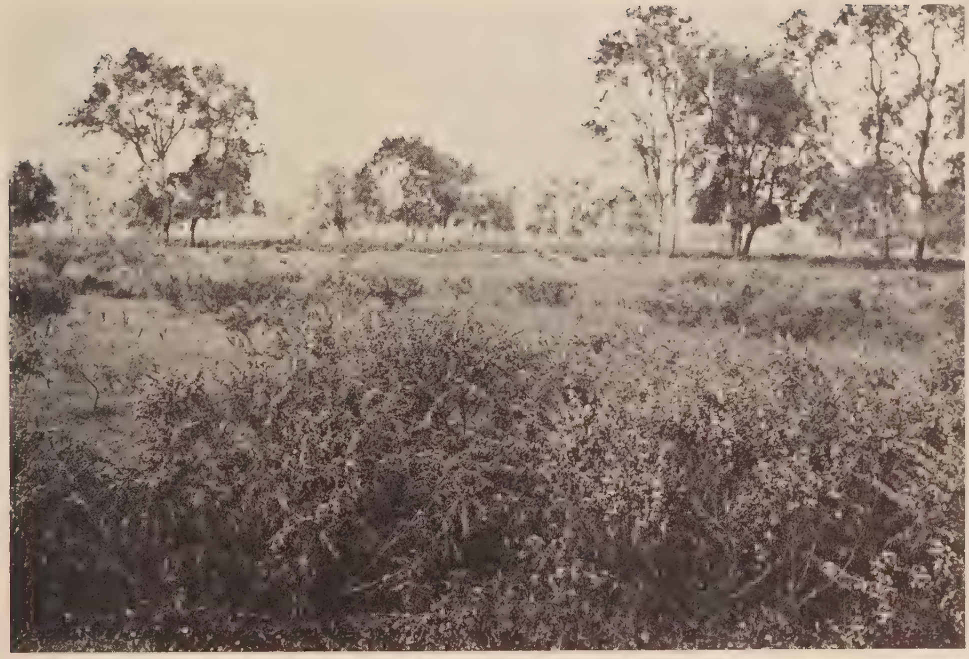

Fig. 1. The shrubs *Thymalea lythroides* on which adults of *Rhizotrogus carduorum*, Er., were found in number. (M' krenza forest).

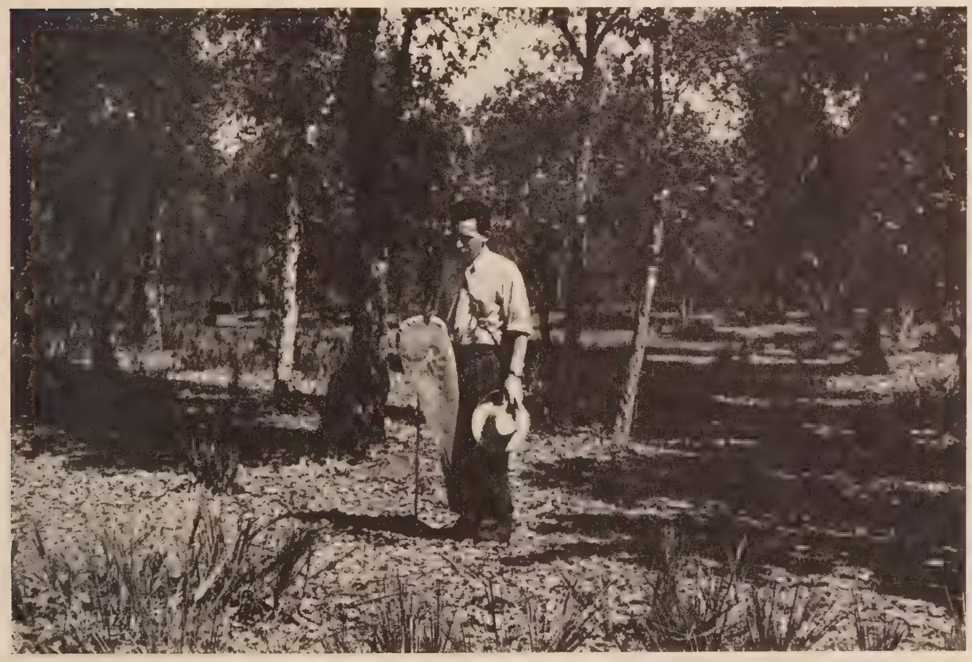

Fig. 2. Zaers forest (M' krenza) where larvæ of *R. carduorum*, Er., and *A. semivillosus*, Fairm. were found in great numbers and parasitised by *Dexiomorpha picta*, Meig.

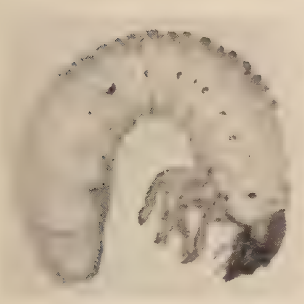

Fig. 1.

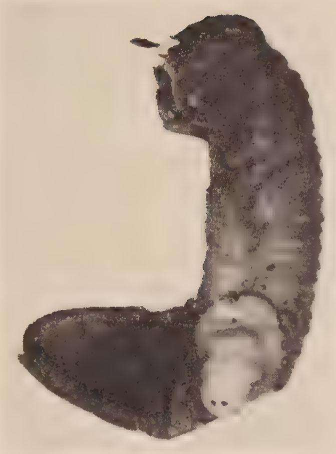

Fig. 2.

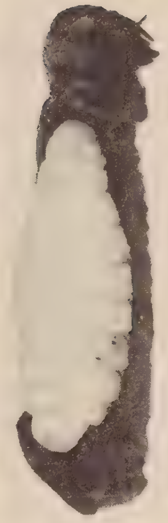

Fig. 3.

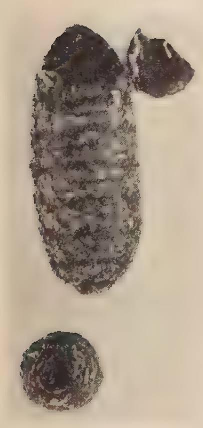

Fig. 4.

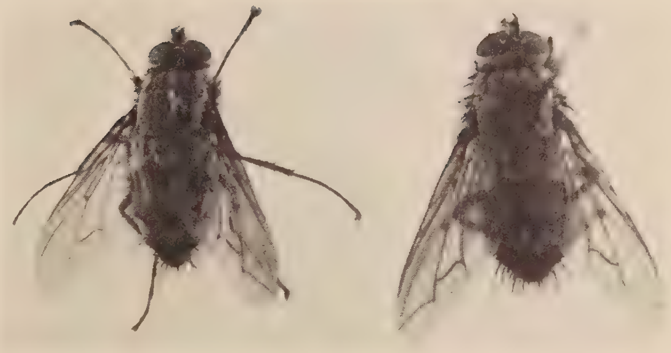

Fig. 5.

Fig. 1. Larva of *Rhizotrogus carduorum*, Er., showing external sign of parasitism (× 3).

Fig. 2. Larva of *Dexiomorpha picta*, Meig., before leaving its host (× 3).

Fig. 3. Larva of *D. picta* outside its host, full-grown (× 3).

Fig. 4. Puparium of *D. picta*, Meig. (× 3).

Fig. 5. Adult flies of *D. picta*, Meig. (× 3).

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st January and 31st March, 1940 :—

AGRICULTURAL RESEARCH INSTITUTE, WAD MEDANI :—203 Orthoptera ; from the Sudan.

Dr. G. BONDAR :—371 Coleoptera and 300 early stages ; from Brazil.

Prof. P. A. BUXTON, London School of Tropical Medicine :—96 Diptera ; from various localities.

Prof. G. D. H. CARPENTER :—197 Coleoptera ; from New Caledonia.

Dr. A. CHIAROMONTE :—2 Diptera, 20 Coleoptera, 41 Parasitic Hymenoptera, 19 Lepidoptera and 4 larvae, and 24 Rhynchota ; from Abyssinia.

CHIEF PLANT PROTECTION OFFICER, JERUSALEM :—31 Parasitic Hymenoptera, 120 Formicidae, and 15 species of Coccidae ; from Palestine.

THE COMMISSIONER, MONTSERRAT :—350 Isoptera.

Mr. G. H. CORBETT, Government Entomologist :—62 Diptera, 20 Coleoptera, 137 Parasitic Hymenoptera, 30 other Hymenoptera, 99 Lepidoptera, 39 Rhynchota, and 4 Orthoptera ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—351 Diptera, 283 Coleoptera, 206 Parasitic Hymenoptera, 105 other Hymenoptera, 1,295 Rhynchota, and 1 species of Mite ; from East Africa.

DIRECTOR OF AGRICULTURE, MAURITIUS :—7 Rhynchota.

Mr. S. DUVDEVANI :—20 Diptera and 13 Coleoptera ; from Palestine.

ENTOMOLOGIST, MANDALAY :—18 Coleoptera ; from Burma.

Mr. R. G. FENNAH, Entomologist :—251 Coleoptera, 5 Hymenoptera, and 8 Rhynchota ; from the British West Indies.

Mr. J. L. FROGGATT, Government Entomologist :—20 Parasitic Hymenoptera ; from New Guinea.

GAME WARDEN, NAIROBI :—90 Dipterous larvae, 26 Coleopterous larvae, 600 Ephemerid larvae, 122 Trichopterous larvae, and 4 Shells ; from Kenya Colony.

Mr. J. C. M. GARDNER, Systematic Entomologist :—25 Curculionidae ; from the United Provinces, India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—109 Coleoptera ; from the Punjab, India.

Mr. G. H. E. HOPKINS, Medical Entomologist :—39 Tabanidae and 9 other Diptera ; from Uganda.

Dr. J. C. HUTSON, Government Entomologist :—19 Lepidoptera and 5 pupa-cases ; from Ceylon.

IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS, CAMBRIDGE :—2 Curculionidae and 9 larvae ; from South America.

IMPERIAL ENTOMOLOGIST, NEW DELHI :—33 Diptera and 14 pupa-cases, 53 Coleoptera, 24 Lepidoptera, 28 Rhynchota, 19 Orthoptera, 2 Chrysopidae, and 2 Odonata ; from India.

Mr. R. A. LEVER, Government Entomologist :—56, Diptera 78 Coleoptera and 30 early stages, 132 Parasitic Hymenoptera, 4 other Hymenoptera, 8 Lepidoptera, 19 Thysanoptera, 3 Cimicidae, 1 species of Coccidae, 43 other Rhynchota, and 2 Orthoptera ; from the Fiji Islands.

Mr. E. Mc. C. Callan :—36 Coleoptera and 159 Rhynchota ; from Trinidad.

Mr. A. P. G. Michelmore :—5 Orthoptera attacked by Mites ; from Kenya Colony.

Mr. H. M. Morris, Government Entomologist :—44 species of Coccidae ; from Cyprus.

Mr. J. Muggeridge, Government Entomologist :—2,500 Mites ; from New Zealand.

Natal Museum, Pietermaritzburg :—2 Dipterous larvae ; from Natal.

Mr. B. A. O'Connor, Entomologist :—30 Coleoptera, 10 Parasitic Hymenoptera, and 2 species of Coccidae ; from New Guinea.

Mr. J. Palmoni :—155 Coleoptera, 85 Parasitic Hymenoptera, 57 other Hymenoptera, 113 Lepidoptera, and 144 Orthoptera ; from Palestine.

Mr. S. A. Rau :—30 Isoptera ; from South India.

Mr. J. Risbec :—99 Diptera and 12 early stages, 1,727 Coleoptera and 44 early stages, 1,476 Parasitic Hymenoptera and 50 cocoons, 27 other Hymenoptera, 139 Lepidoptera and 2 larvae, 54 Thysanoptera, 4 species of Coccidae, 3 species of Aphidae, 3 species of Aleurodidae, 576 other Rhynchota, 151 Orthoptera, 4 Dermaptera, 20 Collembola, 4 Ticks, 2 Spiders, 2 Scorpions, 4 Centipedes, 6 Millipedes, and 3 species of Parasitic Worms ; from Senegal.

Mr. E. Rivnay :—27 Tabanidae and 79 other Diptera ; from Palestine.

Selangor Museum, Kuala Lumpur :—29 Coleoptera ; from Malaya.

Dr. A. Shulov :—51 Coleoptera ; from Palestine.

Mr. F. G. Simmonds :—1 Coleopterous larva ; from France.

Dr. A. L. Tonnoir, Senior Research Officer :—7 Coleoptera, 11 Parasitic Hymenoptera, and 1 species of Coccidae ; from Australia.

Mr. F. Wilson :—5 Coleoptera and 18 Parasitic Hymenoptera ; from France.

THE DISTRIBUTION AND MIGRATIONS OF *LOCUSTA* IN EUROPE.

By Z. V. Waloff, B.Sc.

Imperial Institute of Entomology.

Introduction.

Locusta migratoria, L., is frequently found in the British Isles, and it was thought that the establishment of its probable origin would prove not only of local interest, but could throw some light on the extent and conditions of locust migrations in the temperate belt, as compared with the better known migrations under tropical conditions. With this end in view a critical survey was made of the extensive literature on the outbreaks of this species in Europe, and the records of occurrences in the British Isles were correlated with the events on the continent. In addition the available specimens taken in this country and in different parts of the continent were studied biometrically, to determine their racial affinities. This study made possible some preliminary conclusions on the distribution and origin of endemic colonies of *Locusta* in central and northern Europe, on the source of European and British invasions, and on the types of long-range migrations in swarming Acrididae generally.

Distribution and Outbreak Areas in Europe.

L. migratoria has been recorded from practically every European country, and according to Uvarov (1928) its solitary phase may occur anywhere up to 60°N. It appears, however, that the majority of records refer to immigrants, and the areas permanently inhabited by this species are more restricted, while the outbreak areas, where phase transformation and swarming may occur, are more restricted still. The typical habitats of *L. migratoria* are the deltas of large rivers in semi-desert countries (Uvarov, 1936). In European Russia, which is inhabited by two different subspecies of *L. migratoria*, the outbreak areas of the southern subspecies *L. migratoria migratoria* (L.) are situated in the desert, sub-desert and steppe zones of southern Russia, and can be divided into two main groups. The first, or the *Caspian group*, comprises the following : the outbreak areas in the reed-beds of the rivers Terek and Sulak in Daghestan, the areas lying along the north-western and northern shores of the Caspian Sea, including the deltas of the Volga and Ural Rivers, the valley of Kuma and the Manych depression ; and the outbreak areas round the scattered lakes of the Kalmuk Republic. The second, which it is proposed to call the *East Pontian group*, consists of the outbreak areas along the south-eastern shore of the Sea of Azov and the lower course of the Kuban River (Predtechensky, Zhdanov and Popova, 1935). During the outbreak years swarms of *L. m. migratoria* formed in these areas may emigrate for long distances.

To these two groups must be added a third one, which it is proposed to call the *West Pontian group*. It lies in the same steppe belt as the East Pontian group, and is also inhabited by *L. m. migratoria* (see p. 219). Formerly it comprised the reed-beds in the lower valley and the huge deltaic region of the Danube in Rumania (Knechtel, 1938 ; Nikolsky, 1925), the lower valleys of the Sereth and Pruth Rivers in southern Bessarabia, and the reed-beds in the lower valleys of Dniestr, Bug and Dniepr Rivers in southern Ukraine, where swarms appeared for the last time in 1884, 1886 and 1893 respectively. Since then the Ukrainian areas have become extinct, except for a small outbreak in the reed-beds of Dniepr in 1912, which may have been due to immigration. Similarly the outbreak area along the lower Danube was thought to have become extinct (Nikolsky, 1925). Here the extension of agriculture and cultivation of the flood plain forced the locusts to retreat to the main breeding area in the reed-beds of the delta. However, small outbreaks occurred in the delta in 1899–1902, 1906–1912 and 1923–1924, and an important one between 1927 and 1933. Previous to the last outbreak, parts of the delta were drained by raising the banks of river channels, and the newly drained areas, which were not immediately cultivated, offered suitable sites for breeding and building up of swarms (Knechtel, 1938).

In the West Pontian region *L. m. migratoria* usually produces one generation a year. The winter is passed in the egg-stage, hoppers appear in May and adults in early July (Vereschagin, 1931, 1932). As will be shown later, the locusts produced in the West Pontian outbreak areas were largely responsible for the invasion of central, north and north-western Europe.

The second subspecies of *L. migratoria* found in European Russia is *L. m. rossica* (Uvarov & Zolotarevsky, 1929). This occurs in the forest and forest steppe zones of Central Russia, on fields with open sandy soils, lying on higher ground, and exposed by deforestation (Predtechensky, 1930). Its outbreak areas are situated in the south-eastern part of White Russia and the north-western part of the Kiev district of the Ukraine; along the tributaries of the Oka River between Tambov and Kasimov, along the middle Volga between Kazan and Syzranj, and in the valley of the Voronezh River (Predtechensky, Zhdanov & Popova, 1935). This subspecies may swarm in favourable years, but has not been recorded to emigrate for long distances.

In the Mediterranean Europe, *Locusta* has been recorded from Portugal and Spain (Burr, 1910; Fischer, 1853), southern France (Burr, 1910; Chopard, 1922), Italy (Burr, 1910; Fischer, 1853), Dalmatia and Greece (Fischer, 1853). In the Western Mediterranean region, which is not liable to invasions from the West Pontian outbreak areas and is inhabited by a distinct West Mediterranean "race" (see pp. 218–219), *Locusta* passes through one generation a year, the adults appearing from July onwards (Burr, 1910), and may hibernate in the adult stage (Chopard, 1922). The locusts normally exist there in the solitary phase, but the possibility of local outbreaks is not excluded, for in 1936 numerous accumulations of *Locusta*, ranging from ph. *solitaria* to ph. *gregaria* were observed in many parts of peninsular Italy, particularly round Naples (Jannone, 1936).

The position in central, northern and north-western Europe, which are all liable to be invaded by migrants from the West Pontian region, is less clear. However, scattered endemic colonies of *Locusta* exist permanently in certain localities (fig. 1) in some of which they may become sufficiently numerous to produce local outbreaks.

The Pannonian plain was long believed to have been one of the sources of European invasions (Filipjev, 1926), but since the outbreaks in Hungary usually followed the appearance of swarms in the West Pontian region, it is more probable that it was only a secondary breeding area. Since the regulation of the channels of the Danube and Theiss at the end of the last century and the drainage and cultivation of the former reed-beds in their flood plains, *Locusta* has almost entirely disappeared from Hungary (Jablonowsky, 1926).

An apparently independent colony of *Locusta* used to inhabit the reed-beds on the flat marshy shores of Neusiedlersee (eastern Austria), where a local outbreak occurred in 1858 (Turk, 1858). However, during a survey carried out there in 1907 by Karny (1908), no *Locusta* could be found.

In Switzerland and the Tyrol *Locusta* has been recorded in many localities (Fruhstorfer, 1921; Meyer-Durr, 1860). Permanent endemic colonies which occasionally give rise to local outbreaks exist in Valais, Berne and Grisons Cantons. According to Farquet (1931) in Valais *Locusta* inhabits the sand-dunes and reed-beds bordering the channel of the Upper Rhone. Outbreaks occurred after exceptional floods which left extensive sand deposits and thus provided suitable breeding sites. This occurred in 1747, 1836–1839 and in 1857–1858. In the last named year swarms from the Rhone valley spread to Vaud, Friburg, Berne, Soleure and Argovie Cantons in Switzerland and to Isère Department in France, where they did much damage in the neighbourhood of Bourg d'Oisans in the valley of Romanche (Bellevoye, 1892). In this century small outbreaks occurred at Martigny, Lower Valais, in 1906 and 1911, but since the regulation of the Upper Rhone the factors favouring excessive multiplication of *Locusta* have been largely eliminated.

In Berne there was a local outbreak in 1875, when numerous hoppers appeared near Erlach on the sandy plain exposed by the low level of the Bieler Lake (Fruhstorfer, 1921).

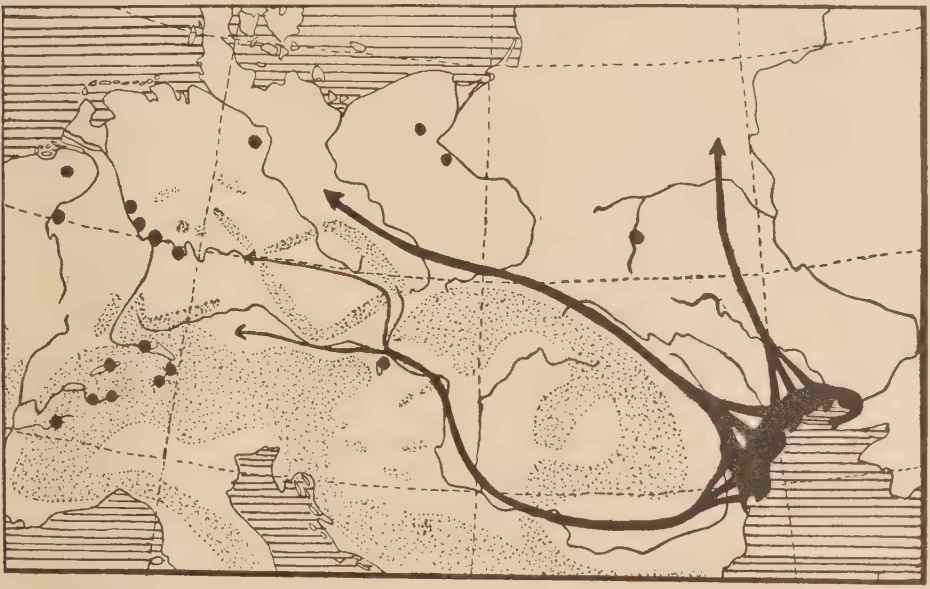

Fig. 1. Map showing distribution and migration routes of *Locusta* in Europe.
Solid black.—The West Pontian outbreak area of *L. m. migratoria.*
Arrows.—Major migration routes of swarms of *L. m. migratoria.*
Black dots.—Endemic colonies of *L. m. rossica* and allied " races."
Stippled.—Mountainous areas.

In Grisons *Locusta* occurs up to the altitude of 700 metres, in the valleys of the Rhine and its tributaries, where again it is usually found on the sandy alluvium and reed marshes near the river channels (Nadig, 1930–1931). In 1874 they were exceptionally numerous in the Flascher Thal. The heavy snowfall during that winter and the very warm spring in 1875 favoured the survival and hatching of the eggs, and in summer 1875 there were outbreaks in the valleys of Vorderrhein, Hinterrhein and Landquart, and of the Rhine in Grisons and St. Gallen Cantons, and in Lichtenstein (Fruhstorfer, 1921).

According to Brunner von Wattenwyl (1882) another isolated colony of *Locusta* exists in the Rhine Valley in the Schaffhausen Canton, though there are no records of outbreaks in this area.

It is very probable that similar colonies exist in the Savoy Alps, for in 1850 there was a small local outbreak on the left bank of the Isère near St. Pierre d'Albigny (Departement de Savoie) (Genin & Bonjean, 1850).

North of the Alpine belt scattered endemic colonies of *Locusta* apparently exist in the valleys of Main and the middle Rhine. Already Fischer (1853) records *Locusta* from the neighbourhood of Frankfurt-on-Main ; in 1901 it was taken on several occasions near Aschaffenburg, and in 1907 at Dorningheim (Rudy, 1925). In the middle Rhine valley it was found every year between 1875 and 1880 and again in 1913 near Bonn, and has been recorded from Wahner Heide between Bonn and Cologne (Rudy, 1925 ; Zacher, 1917). Separate colonies live on dry heaths near Elberfeld and Düsseldorf, particularly on the Hildener Heide near the latter (Zacher, 1917, and see p. 215). According to the information kindly supplied by Dr. C. Willemse of Eygelshoven, *Locusta* is to be found every year in Holland on sandy heaths overgrown by poor grass, heather and small birches, at Brunsummer Heide, near Sittard, Limburg Province.

A colony of *Locusta* exists in the valley of Styr, in Volhynia, eastern Poland, where it finds suitable breeding conditions on the dry, sun-exposed banks along the middle course of the river (Kaminski, 1938).

A number of isolated endemic colonies are scattered over the North-European plain proper. In Western Poland, apparently indigenous *Locusta* was found in 1913 on a sandy waste overgrown by sparse grass and scattered pines, to the south of Thorn. In Western Prussia there was a local outbreak in Deutsch Krone district in 1888, when masses of hoppers appeared on forest clearings occupied by fallow fields with light sandy soils (La Baume, 1920). The conditions here approach very closely those under which *L. m. rossica* lives in Central Russia (see p. 212) and it is very likely that locusts occurring in Western Prussia belong to the same subspecies. It is probable that colonies of *Locusta* exist in other parts of eastern and central Germany, in particular in Mark Brandenburg and near Magdeburg in Saxony, and the outbreaks reported in Germany between 1870 and 1880 (see p. 233) may well have been due to the breeding up of local populations. Further west *Locusta* may exist permanently on the sandy Lüneburger Heide in Hanover, where it was observed in 1793 (Ritter, 1838), repeatedly in 1876 to 1878 and again in 1900 (Weidner, 1938). It is also found in Holland, near Helmond, North Brabant Province (Willemse).

The Systematic Position of Locusta from different Parts of Europe.

Most of the subspecies of the widespread *L. migratoria*, Linné, have been differentiated by the biometrical characters of ph. *gregaria* (Zolotarevsky, 1929 ; Uvarov, 1936). Such characters for both phases have been roughly worked out only for the two subspecies occurring in Russia, *i.e.*, *L. m. rossica* (Uvarov & Zolotarevsky, 1929) and *L. m. migratoria* (L.). Table I summarises the available published data on the biometrics of these subspecies, and includes the measurements of *L. m. migratoria* ph. *gregaria* made in 1912 in northern Caucasus by Dr. B. P. Uvarov and kindly supplied by him.

Specimens of *Locusta* from different parts of Europe available in the British Museum collections were studied biometrically. In all cases the series were too small for statistical treatment. The lots from different localities are tabulated according to the lengths of their femora and elytra in Tables II and III, which serve for comparison of such lots to each other, and also demonstrate the range of variation within them. To determine their systematic affinities their measurements were compared with those of *L. m. migratoria* and *L. m. rossica*, given in Table I.

A series of *Locusta* collected over a number of years on the Hilden heath, near Düsseldorf, Western Germany, was presented in 1910 to the British Museum by W. F. Kirby. Their biometrical measurements and ratios are given in Table IV.

TABLE I.

Measurements of phases solitaria *and* gregaria *in* L. m. rossica *and* L. m. migratoria (*in cms.*).

	E ♂	Most frequent value ♂	F ♂	Most frequent value ♂	E ♀	Most frequent value ♀	F ♀	Most frequent value ♀
			Phase solitaria					
L. m. rossica								
N.W. part of Spassky d., Penza Prov. in 1922–24 (Predtechensky, 1928)	3·3–4·3	3·7–3·9	1·7–2·2	2·0	3·7–5·3	4·7	2·0–2·6	2·4
Trubchevsk d., Briansk Govt., in July - Aug. 1922 (Gause 1928)	3·941		2·004		4·78		2·395	
L. m. migratoria								
Volga delta, 1925 & 1926 (Predtechensky, 1928)	4·3–4·9	4·7	2·2–2·6	2·4	5·3–5·9	5·7–5·9	2·7–3·0	2·8–3·0
			Phase gregaria					
L. m. rossica								
N.W. part of Spassky d., Penza Prov. in 1922–24 (Predtechensky, 1928)	3·5–4·3	3·7–3·9	1·7–2·2	1·9–2·0	4·1–5·3	4·7	2·0–2·5	2·3
L. m. migratoria								
Volga delta, 1925 & 1926 (Predtechensky, 1928)	3·9–5·5	4·9–5·1	2·0–2·6	2·3–2·4	4·9–5·7	5·3	2·0–2·6	2·4–2·5
N. Caucasus 1926 (Gause 1928) ...	4·74-5·58		2·26-2·68		M 5·47		2·13-2·79	
Achikulak & Kazenny Uchastki, Stavropol Prov. 1912 (Dr. Uvarov's measurements)	5·0–5·6		2·3–2·6		4·9–5·9		2·2–2·6	

In this lot the measurements of femora and elytra in the females and of the femora in the males fall within the limits for *L. m. rossica* but are all below its most frequent values; in about half the males the elytra are within the limits for *L. m. rossica*, and in others they are definitely below the lower limit for this subspecies. Similarly, when measurements of two specimens of *Locusta* collected in 1935 from the indigenous population of Brunsummer Heide, Limburg Province, eastern Holland (see Tables II and III), are compared with those for *L. m. rossica*, it is seen that the elytra and femora in the female and the femora in the male are within the limits of this subspecies, but below the most frequent values; while the elytra of the male are shorter. It follows that these two areas are inhabited by a distinct " race " of *Locusta* which is akin to *L. m. rossica*, but rather smaller. (The term " race " is used provisionally, and without any definite systematic meaning, for the available series is too small for a more exact determination.)

TABLE II.

Distribution of the length of posterior femur (in cms.).

	1·70	1·80	1·90	2·00	2·10	2·20	2·30	2·40	2·50	2·60	2·70	2·80	2·90	3·00	3·10	3·20	3·30
Females.																	
British Isles, ph. *gregaria*								6	6	3							
,, ,, ph. *transiens*									3	4	4	3	1		1		
,, ,, ph. *solitaria*															3		
Rumania, ph. *gregaria*									1	1	1						
,, ph. *transiens*									1	1		1		1		1	
,, ph. *solitaria*														1			
Holland (Limburg Prov.), ph. *solitaria* ...							1										
Germany (Hilden), ph. *solitaria*					1	5	4	1									
France (Isère), ph. *solitaria*...						1											
France (South), ph. *solitaria*									1	3	1		1				
Italy, ph. *solitaria*											4		1				
Algeria, ph. *solitaria*								1					1				
Males.																	
British Isles, ph. *gregaria*						1	1		1								
,, ,, ph. *transiens*							1	1	5								
Rumania, ph. *gregaria*		1			1				1	1							
,, ph. *transiens*							3										
Holland (Limburg Prov.), ph. *solitaria* ...		1															
Germany (Hilden), ph. *solitaria*	1	4	3														
France (Isère), ph. *solitaria*...				1													
France (South), ph. *solitaria*				4	1												
Italy, ph. *solitaria*				2	3	1		1									
Algeria, ph. *solitaria*							1										

TABLE III.

Distribution of length of elytron (in cms.).

	3·10	3·20	3·30	3·40	3·50	3·60	3·70	3·80	3·90	4·00	4·10	4·20	4·30	4·40	4·50	4·60	4·70	4·80	4·90	5·00	5·10	5·20	5·30	5·40	5·50	5·60	5·70	5·80	5·90	6·00	6·10	6·20	6·30
Females.																																	
British Isles, ph. *gregaria*																							2	1	3	6							
,, ,, ph. *transiens*																				1		1	2		4	4			1			1	1
,, ,, ph. *solitaria*																						1					1		1				
Rumania, ph. *gregaria*																											2		1				
,, ph. *transiens*																						1				1	1			1			1
,, ph. *solitaria*																									1								
Holland (Limburg Prov.), ph. *solitaria*									1																								
Germany (Hilden), ph. *solitaria*									1		2	4	3	1																			
France (Isère), ph. *solitaria*															1																		
France (South), ph. *solitaria*																1		1	1	1	1	1											
Italy, ph. *solitaria*																		2		1	2												
Algeria, ph. *solitaria*																		1	1														
Males.																																	
British Isles, ph. *gregaria*																				1		1		1									
,, ,, ph. *transiens*																			2	3	1												
Rumania, ph. *gregaria*													1		1										1			1					
,, ph. *transiens*																1				2				1									
Holland (Limburg Prov.), ph. *solitaria*		1																															
Germany (Hilden), ph. *solitaria*	1	3	3	2																													
France (Isère), ph. *solitaria*							1																										
France (South), ph. *solitaria*					2	1	1	1																									
Italy, ph. *solitaria*				1			1	1	3	1																							
Algeria, ph. *solitaria*									1																								

TABLE IV.

Measurements (in cms.) and ratios of Locusta *from Hilden heath, near Düsseldorf.*

Sex	E	F	P	M	H	C	E/F	P/C	H/C	M/C
♂	3·44	1·85	·84	·47	·67	·53	1·86	1·58	1·26	·89
♂	3·35	1·89	·70	·49	·70	·52	1·77	1·35	1·35	·94
♂	3·45	broken off	·72	·49	·68	·54	—	1·33	1·26	·91
♂	3·25	1·90	·75	·48	·66	·54	1·71	1·39	1·22	·89
♂	3·36	1·90	·70	·49	·68	·54	1·72	1·29	1·26	·91
♂	3·20	1·80	·71	·49	·63	·53	1·77	1·34	1·19	·92
♂	3·15	1·90	·73	·49	·65	·55	1·66	1·33	1·18	·89
♂	3·22	1·81	·71	·50	·66	·52	1·78	1·37	1·27	·96
♂	3·30	1·76	·75	·50	·65	·53	1·88	1·42	1·23	·94
♀	4·45	2·45	·90	·61	·87	·71	1·82	1·27	1·23	·86
♀	approx. 4·35	2·40	1·0	·65	·92	·75	1·81	1·33	1·23	·87
♀	3·95	2·16	·95	·64	·85	·69	1·83	1·38	1·23	·93
♀	4·18	2·23	·92	·60	·85	·69	1·87	1·33	1·23	·87
♀	4·25	2·35	·95	·64	·89	·71	1·81	1·34	1·25	·90
♀	4·20	2·39	·95	·66	·90	·74	1·76	1·28	1·22	·89
♀	approx. 4·14	2·29	·94	·62	·85	·70	1·80	1·34	1·22	·89
♀	4·32	2·27	·94	·65	·87	·70	1·90	1·34	1·24	·94
♀	4·23	2·29	·92	·60	·85	·70	1·85	1·32	1·22	·86
♀	4·30	2·32	·89	·67	·93	·73	1·85	1·22	1·27	·92
♀	4·20	2·23	·88	·63	·87	·70	1·88	1·26	1·24	·90

Note: E—length of elytron; F—length of posterior femur; P—length of pronotum; M—width of pronotum at the constriction; H—height of pronotum; C—maximum width of head.

The measurements of two undated specimens labelled "Isère" (see Tables II and III) are well within the limits of *L. m. rossica*, and they undoubtedly belong to this subspecies. Brunner von Wattenwyl (1882) states that in Schaffhausen Canton the locusts are "darker and smaller" than those from Eastern Europe. It appears very probable that all the colonies in the Alpine belt belong to *L. m. rossica*.

The measurements and ratios of specimens collected in Western Mediterranean countries (southern France, Italy, Algeria) are given in Table V, which also includes the available printed data on biometrics of *Locusta* from this region. Comparison of their measurements with those for *L. m. rossica* and *L. m. migratoria* (Table I) shows that in both sexes the elytra are within the limits for the former and below those of the latter; in the females the elytron measurements are mostly above the most frequent values for *L. m. rossica*. The femoral measurements of males overlap the upper limit of *L. m. rossica* and the lower limit of *L. m. migratoria*, while those of females are in most cases within the limits for *L. m. migratoria*. It appears that the

TABLE V.

Measurements (in cms.) and ratios of Locusta *from the Western Mediterranean region.*

	Sex	E	F	P	M	H	C	E/F	P/C	H/C	M/C
France (South)											
Cerbère	♂	3·60	2·03	—	·52	·70	·52	1·78	—	1·35	1·0
Cannes	♂	3·50	2·05	·86	·55	·75	·53	1·71	1·62	1·42	1·04
Cannes	♂	3·82	2·06	·84	·55	·74	·54	1·86	1·56	1·37	1·02
Cannes	♂	3·70	2·10	·77	·50	·70	·55	1·77	1·40	1·27	·91
Gênes, 23.ii.1878 (Zolotarevsky 1933)... ...	♂	—	—	—	—	—	—	1·84	1·44	1·37	·98
Corsica	♂	3·59	2·05	·84	·50	·74	·50	1·75	1·68	1·48	1·0
Cagnes, viii–ix.1924 ...	♀	4·85	2·65	1·10	·73	1·01	·75	1·83	1·47	1·35	·97
Cannes	♀	5·25	2·71	1·26	·73	1·09	·78	1·94	1·62	1·40	·93
Cannes	♀	4·69	2·65	1·19	·70	1·03	·72	1·77	1·65	1·43	·97
Cannes	♀	5·18	2·99	1·21	·75	1·10	·80	1·74	1·51	1·38	·94
Cannes	♀	4·92	2·68	1·06	·72	·95	·74	1·85	1·46	1·29	·97
Cannes	♀	5·0	2·51	1·05	·68	·95	·72	1·99	1·46	1·32	·94
Gênes, 23.ii.1878 (Zolotarevsky 1933) ...	♀	—	—	—	—	—	—	1·75	1·50	1·37	·87
Hyères, 29.vi.1898 (Zolotarevsky 1933) ...	♀	—	—	—	—	—	—	1·75	1·52	1·35	·87
Italy											
Ostia, near Rome ...	♂	4·0	2·40	·95	·58	·86	·64	1·67	1·49	1·35	·91
Rome	♂	4·0	2·19	·91	·56	·84	·60	1·83	1·52	1·40	·93
Rome	♂	3·71	2·08	·80	·50	·72	·53	1·78	1·51	1·36	·94
Taranto, Puglia, 1918 ...	♂	3·82	2·15	·99	·58	·87	·58	1·79	1·71	1·50	1·0
Turin, 17.ix.1918... ...	♂	4·15	2·17	·93	·55	·72	·55	1·91	1·63	1·31	1·0
Arquata, Ascoli, x.1918 ...	♂	3·40	2·04	·70	·52	·70	·51	1·67	1·37	1·37	1·02
,, ,, ,, ...	♂	4·08	2·26	·95	·59	·82	·61	1·81	1·56	1·35	·97
Ostia, near Rome ...	♀	5·10	2·75	1·19	·74	1·19	·74	1·86	1·61	1·61	1·0
Arquata, Ascoli, ix.1918	♀	4·85	2·78	1·15	·70	1·0	·75	1·75	1·53	1·33	·93
,, ,, ,,	♀	4·85	2·75	1·14	·70	1·04	·74	1·77	1·54	1·41	·95
,, ,, ,,	♀	5·13	2·91	1·25	·75	1·10	·79	1·76	1·58	1·39	·95
,, ,, x.1918	♀	5·03	2·75	1·10	·72	1·04	·74	1·83	1·49	1·40	·97
Algeria											
Biskra	♂	4·10	2·31	·90	·59	·85	·60	1·78	1·50	1·42	·98
Algeria (average figures from Uvarov & Hamilton 1936)	♂	3·96	2·25	·85	·59	·80	·62	1·76	1·37	1·30	·95
Biskra	♀	4·87	2·95	1·10	·70	·98	·78	1·65	1·41	1·26	·90
Saida 1923	♀	4·95	2·45	1·10	·76	1·05	·78	2·01	1·41	1·35	·97
Algeria (average figures from Uvarov & Hamilton 1936)	♀	4·90	2·80	1·05	·75	1·05	·73	1·75	1·44	1·44	1·03

locusts from these countries are intermediate in size between the two subspecies, and it is proposed to designate them provisionally as the Western Mediterranean "race."

In Table VI are given the measurements and ratios of *Locusta* taken in the Danube delta and in Bessarabia, kindly made by Miss Arkhangelskaia and communicated by Mr. B. V. Vereschagin of Statiunea Fitopatologica, Chisinau. Their measurements, with one exception, fall within the limits of *L. m. migratoria* (Table I), or exceed them. The exception is a male, the femora of which (1·80 cm.) are below the lower limit of *L. m. migratoria* and within the limits for *L. m. rossica* ; its elytra, however, are well within the limits for *L. m. migratoria*. It can be concluded, therefore, that the Rumanian specimens belong to the latter subspecies.

TABLE VI.

Measurements (in cms.) and ratios of Locusta *from Rumania.*

	Sex	E	F	E/F	Phase
Kishinev, 12.viii.1912	♀	5·75	2·85	2·02	Transiens
Kishinev, 23.vi.1937	♀	5·50	3·0	1·83	Solitaria
Leontina, Tichin Dist., 15.vii.1938	♀	5·70	2·59	2·20	Gregaria
,, ,, ,, 15.vii.1938	♀	5·60	2·65	2·11	Transiens ?
,, ,, ,, 15.vii.1938	♀	5·70	2·60	2·19	Gregaria
,, ,, ,, 15.vii.1938	♀	6·05	3·0	2·02	Transiens
,, ,, ,, 15.vii.1938	♀	6·30	3·20	1·97	Transiens
,, ,, ,, 15.vii.1938	♀	5·90	2·70	2·18	Gregaria
Tatai, Tulcea Dist., 19.vii.1939	♀	5·20	2·59	2·01	Transiens
Kishinev, 21.viii.1930	♂	4·35	1·80	2·46	Gregaria
Kishinev, 30.ix.1930	♂	4·55	2·10	2·17	Gregaria
Leontina, Tichin Dist., 15.vii.1938	♂	5·80	2·55	2·27	Gregaria
,, ,, ,, 15.vii.1938	♂	5·55	2·60	2·14	Gregaria
,, ,, ,, 15.vii.1938	♂	5·40	2·65	2·04	Transiens
Tatai, Tulcea Dist., 19.vii.1939	♂	4·60	2·30	2·00	Transiens
,, ,, ,, 19.vii.1939	♂	5·0	2·35	2·13	Transiens ?
Kishinev, 20.viii.1939	♂	5·0	2·35	2·13	Transiens ?

The measurements and ratios of *Locusta* taken in the British Isles are given in Table VII. These specimens are either in the collections of the British Museum or in provincial Museums, from which they were borrowed for study. From Tables II and III it is seen that in British specimens of both sexes the elytra are much longer than in the Hilden, Limburg or Isère specimens, and that this is also true for the femora of the males. In females, the femora of British specimens are longer than those from Limburg or Isère, but there is a slight overlapping in the femoral measurements of British specimens of ph. *gregaria* and of Hilden specimens, which all belong to ph. *solitaria* ; the femora of British specimens of phases *transiens* and *solitaria*, which are usually larger than ph. *gregaria*, are much longer than those of the Hilden specimens. It follows that *Locusta* taken in the British Isles is systematically distinct from those occurring in these three localities. There is considerable overlapping in the femoral measurements, in both sexes, of the British and Western Mediterranean specimens and a slight overlapping in the sizes of their elytra in females. However, the elytra of Western Mediterranean males are much smaller than those of British males, and the upper limits of femoral and elytral measurements of British specimens, in both sexes and in all phases, go well beyond the upper limits of the Western Mediterranean specimens, so that the two lots are again systematically distinct.

Tables II and III also bring out the great similarity in the femoral and elytral measurements of both sexes, between the British and Rumanian specimens, which

TABLE VII.

Measurements (in cms.) and Ratios of Locusta *taken in the British Isles.*

Locality	Date	Sex.	E	F	E/F	P/C	H/C	M/C	Pronotum	Phase.
Littlehampton, Sussex	1846	♂	4·96	2·54	1·95	1·24	1·20	·87	Slightly concave	T
Richmond	1846	♀	—	2·70	—	1·20	1·16	·89	Straight	T ?
Hammersmith	ix.1846	♀	5·55	2·63	2·11	1·07	1·10	·86	Slightly concave	G ?
Nash Lighthouse, Glamorganshire (Bristol Channel)	ix.1846	♀	5·50	2·45	2·25	1·18	1·05	·82	Straight	G
Yarmouth, Norfolk	1847	♂	5·24	2·28	2·30	1·25	1·12	·88	Slightly concave	G
Yarmouth, Norfolk	1847	♀	5·49	2·53	2·17	—	1·12	·84	Straight	G
Millbank, Middlesex	1847	♀	5·64	2·58	2·18	1·16	1·15	·87	Straight	G
Ipswich, Suffolk...	1850	♂	5·20	2·53	2·03	—	1·13	·86	Straight	T
Rhyl, N. Wales ...	1857	♂	5·25	2·10	2·10	1·19	1·13	·81	Slightly concave	T
Exeter, Devon ...	1857	♂	—	2·57	—	1·28	1·19	·86	Slightly concave	T ?
" Solway "	1857	♀	5·51	2·54	2·17	—	1·16	·79	Concave	G
Chatham, Kent ...	1857	♀	—	2·87	—	1·27	1·23	·89	Convex	T ?
Chepstow, Monmouth ...	16.ix.1857	♀	5·0	2·50	2·0	1·15	1·12	·84	Straight	T
Shetlands	1858	♀	5·61	2·58	2·17	—	1·12	·85	Slightly concave	G
Newland, Glanwootton, Dorset	1.ix.1859	♀	5·33	2·46	2·17	1·10	1·06	·84	Slightly concave	G
Harleston, Norfolk	1897	♀	5·33	2·54	2·10	—	1·09	·86		T
Aran Island, Co. Galway	viii.1898	♀	5·70	3·10	1·84	1·46	1·27	·91	Convex	S
Gorleston, Suffolk	viii.1898	♀	5·95	3·17	1·88	1·40	1·32	·93	Convex	S
Calf of Man	30.viii.1899	♀	5·35	2·75	1·94	1·30	1·27	·89	Slightly concave	T
Chelsea ...	11.x.1921	♂	5·22	2·55	2·05	1·24	1·14	·87	Straight	T

TABLE VII—*Continued.*

Measurements (in cms.) and Ratios of Locusta *taken in the British Isles.*

Locality	Date	Sex	E	F	E/F	P/C	H/C	M/C	Pronotum	Phase
Stratford-on-Avon, Warwick	x.1929	♀	—	2·41	—	1·08	1·08	·83	Slightly concave	G ?
Cromer, Norfolk	16.viii.1931	♂	5·44	2·52	2·16	1·29	1·13	·86	Concave	G
Malton, Yorks	ix.1931	♂	5·08	2·35	2·16	1·16	1·13	·85	Slightly concave	G
Yarmouth, Norfolk	viii.1931	♀	—	2·69	—	1·14	1·14	·85	Straight	G ?
Pottersbury, Northamptonshire	ix.1938	♀	6·30	2·96	2·13	1·40	1·32	·93	Very convex	T ?
Holy Island, Northumberland	viii.1938	♀	6·26	3·10	2·02	1·40	1·33	1·01	Convex	T
Rousey, Orkneys	ix.1938	♀	5·24	3·10	1·69	1·34	1·29	·91		S
N. Ronaldshay, Orkneys	12.ix.1939	♀	5·55	2·74	2·03	1·22	1·13	·80	Slightly concave	T
N. Mavine, Shetlands	15.ix.1939	♀	5·68	2·60	2·18	1·13	1·13	·85	Slightly concave	G
No locality, no date, in or before 1826		♀	5·60	2·66	2·10	1·16	1·15	·78	Straight	T
		♀	5·66	2·50	2·27	1·18	1·10	·87	Straight	G
		♀	5·64	2·43	2·32	1·12	1·15	·92	Very slightly convex	G
		♀	5·50	2·44	2·25	1·07	1·10	·85	Concave	G
Folkestone, Kent, in or before 1861		♀	5·65	2·56	2·21	1·16	1·22	·89	Slightly concave	G
Kennford, Devon, in or before 1921		♀	5·66	2·66	2·13	1·21	1·33	·95		T
Hartlepool	—	♂	5·35	2·48	2·16	1·34	1·22	·82	Straight	T
Oxford	—	♀	5·91	2·82	2·10	1·18	1·35	·86	Straight	T
Berwickshire	—	♀	5·65	2·68	2·11	1·16	1·14	·85	Concave	T
Yorkshire	—	♀	5·65	2·85	1·98	—	1·16	·88	Straight	T
No locality, no date		♂	4·96	2·33	2·13	1·21	1·1	·81	Slightly concave	T
		♀	5·31	2·46	2·16	—	1·11	·85	Straight	G
		♀	5·58	2·64	2·11	1·23	1·12	·83	Slightly concave	T
		♀	5·58	2·73	2·04	1·14	1·09	·81	Slightly concave	T
		♀	5·28	2·50	2·11	1·09	1·10	·86	Slightly concave	T

obviously belong to the same systematic group. A comparison of measurements of British specimens with Table I shows that with one exception they fall within the limits established for *L. m. migratoria* and in some cases even exceed them. The exception is a female taken in Chepstow in 1857, the elytra of which (5·0 cm.) are below the upper limit of *L. m. rossica*, and below the lower limit of *L. m. migratoria*. The length of its femora is, however, well above the upper limit for *L. m. rossica*, and it can be concluded that the British specimens all belong to *L. m. migratoria*, as do those from Rumania.

The Origin of Endemic Colonies of Locusta in Central and Northern Europe.

The foregoing account of endemic colonies in central and northern Europe is obviously very incomplete, and it is hoped that collectors in all parts of Europe will pay special attention to *Locusta* and put on record all observed cases of breeding, as well as the biometrical characteristics of specimens taken in their areas. However, even from this account it is clear that the distribution of *Locusta* is not continuous and that it occurs only in special localities where local conditions favour its survival. In the narrow Alpine valleys this is ensured by cold winters with sufficient snow cover, and by the high degree of insolation in summer. North of the Alpine belt it is found in sheltered river valleys and on dry heaths with light soils, the ecoclimates of which are relatively more continental than in the surrounding areas.

The origin of the endemic colonies of *Locusta* scattered over central and northern Europe is probably similar to that of *L. m. rossica* in Central Russia. In the boreal period following the last glaciation, during which steppe conditions extended northwards and westwards far beyond their present limits, *L. m. migratoria* spread into Central Russia from its original habitat in the Caspian-Pontic lowlands. In the subsequent damp Atlantic period when the forests spread southwards, the species must have survived in Central Russia in the form of relict colonies in specially favourable situations. The present breeding places are secondary and have been produced by deforestation (Predtechensky, 1928). The damper and cooler summer conditions under which the relict colonies have existed since the termination of the boreal period apparently caused *Locusta* to decrease in size, so that a distinct subspecies *L. m. rossica* was produced. This hypothesis is supported by the fact that *Locusta* occurring on the river terraces of the middle Volga, where the climatic, soil and vegetation conditions approach those of the steppe, is, on the whole, larger than *L. m. rossica* in other parts of Central Russia, and closely approaches *L. m. migratoria* (Zolotarev, 1936). The spread of *Locusta* into central and northern Europe probably also occurred during the steppe-like conditions of the boreal period. This is suggested by the occurrence in the neighbourhood of some of the colonies of relict black earth soils, which could only have been formed under climatic conditions characteristic of the steppe. The list of such localities given by Zeuner (1929) includes Thorn, the Main valley and the Limburg Province of Holland. It is also significant that in some of the localities where *Locusta* is found the orthopterous fauna contains other southern elements, *e.g.*, *Ephippigera vitium* (Serv.), *Calliptamus italicus* (L.) and *Arcyptera microptera* (F. W.), near Thorn (La Baume, 1920), *E. vitium* in Limburg and in the Main valley (Zeuner, 1929), and *Aiolopus chinensis*, Karny, *Acrida turrita*, L., and *Homorocoryphus nitidulus* (Scop.), at Neusiedlersee, which is remarkable for the number of species finding there their north-western limit (Franz, 1936). The present-day colonies of *Locusta* in central and northern Europe must, therefore, be the relicts of the former distribution, and the fact that *Locusta* from Holland and Hilden are even smaller than *L. m. rossica* suggests that the process of differentiation from the original *L. m. migratoria* has advanced further in western Europe than in Central Russia or in the Alps.

Outline of History of European Invasions since the 14th Century including the Records for the British Isles.

In attempting to reconstruct the history of European invasions the main difficulties lay in the incompleteness of the records and frequent absence of exact information on dates and localities of locust appearances. Moreover, until recently, records were seldom made of swarming within the outbreak areas themselves, and the plagues were reported only after the swarms had overrun the neighbouring regions. However, from the 16th century clear indications are available that most of the locust plagues invading Europe originated in the West Pontian outbreak areas, for nearly always the commencement of invasions coincided with outbreaks in Ukraine and/or Rumania (except during the periods 1680–1686 and 1866–1881). Thus, breeding in the Danube delta was definitely reported early in the outbreak periods 1745–1754 and 1780–1806, in the reed-beds of the Dniestr and Dniepr and in the Danube delta at the beginning of 1882–1889 period, and in the Danube delta alone during the outbreaks which occurred in this century. The similarity in the sequence in which different countries were repeatedly invaded made possible the reconstruction of the major routes along which the swarms migrated from the West Pontian region (fig. 1). This map differs from those published by Filipjev (1926) and Zolk (1934), but is believed to be more exact, as it is based on a more detailed chronological analysis of the invasion records. Carpenter (1940) in his sketchy outline of European outbreaks merely repeats the conclusions of these authors.

From the West Pontian areas the flying locusts spread, from July onwards, along three main lines, to some extent determined by the major features of relief, *i.e.* (1) in a general northerly direction, leading to invasion of Ukraine and western Russia ; (2) general north-westerly direction via Bessarabia, skirting the curve of the Carpathian mountains into southern Poland, and then keeping to the north of the Tatra Mountains and the Bohemian block into eastern and central Germany ; (3) from the lower Danubian plain into the Pannonian plain, either along the valley of the Danube, or more directly across the Carpathian and Transylvanian mountain passes ; from the Pannonian plain, which probably formed a secondary breeding area, north-westwards along the Danube valley into the Vienna Basin, and from there (*a*) up the Morava valley into Moravia and Bohemia, and then into Bavaria, Thuringia and Saxony, or (*b*) westwards along the Danube valley, across northern Austria to southern Bavaria, Tyrol and Switzerland. The lines (2) and (3) (*a*) may have converged in central Germany. In northern Europe, which except in Poland and eastern Germany was usually reached by small swarmlets and separate individuals only, the locusts appeared in August–September, scattered over a wide front stretching from northern France to southern Finland, and reaching north-westwards to the British Isles and the Scandinavian peninsula.

In the following accounts the European records are summarised and presented as briefly as possible, but the British records (marked with an asterisk) are given in greater detail. In considering the latter it should be borne in mind that the dates on which the specimens were taken, even when these are given, are not necessarily those on which they had reached the locality. In cases of specimens taken on or near the coasts it is safe to assume that the locusts reached the British Isles in that area, but it is often impossible to reconstruct the course along which the locusts spread further inland. In all cases the term locust refers to *Locusta*.

14th Century.

1333–1341. This was a great invasion affecting the greater part of Europe. Its source is not known, but its similarity with later and better known invasions makes it probable that it came from the West Pontian area. Between 1333 and 1339 the locust plague appeared on the one hand in Poland, and on the other in Hungary, Moravia, Bohemia, Austria, Tyrol, Switzerland and even the Lombardy plain.

In Germany, Bavaria, Frankonia, Hessen-Nassau and Saxony were invaded (probably *via* 3 *a*), and Silesia (*via* 2). The infestation continued for several years, either owing to repeated invasions from the east, or to the progeny of original swarms. In 1339 the invasion spread to Alsace and eastern France, and the plague persisted in Hungary, Austria, Bohemia and Poland until 1341 (Dalla-Torre, 1920 ; Fruhstorfer, 1921 ; Keferstein, 1843 ; Keppen, 1870 ; Perlick, 1931 ; Rudy, 1925 ; Weidner, 1938 ; Zacher, 1917).

* During this period some swarms spread to the British Isles (Perlick, 1931).

1344–1347. This was apparently a similar invasion, though on a smaller scale. In 1344 locusts were reported in Hungary, in 1346 in Bohemia, and in 1347 in France (Keferstein, 1843 ; Keppen, 1870).

* In 1347 England was reached by some locusts " from France " (Keferstein, 1843).

15th Century.

1472–1477. Between 1472 and 1475 locusts, evidently originating in the West Pontian areas, flew along route 3 from Moldavia across Transylvannia into Hungary, and from there into Austria and Tyrol (route 3*b*) and Moravia and Bohemia (route 3*a*). Another wave penetrated along route 2 into Poland, and from there into Silesia and Saxony. Locusts survived in Poland till 1476 and in Tyrol till 1477 (Dalla-Torre, 1920 ; Filipjev, 1926 ; Kaminski, 1938 ; Keppen, 1870 ; Perlick, 1931).

16th Century.

1536–1547. In 1536 the plague appeared in western Ukraine and in Poland in the north and in Hungary in the south (Keferstein, 1843 ; Keppen, 1870 ; Rudy, 1925). In 1538 the plague was recorded in Wallachia and Moldavia (Knechtel, 1938), so that the whole of the West Pontian outbreak area must have been functioning. Breeding-up of swarms continued in the following years and Wallachia and Moldavia were again overrun in 1541. In 1542 the swarms spread along routes 1 and 2 into western Russia and Poland, as far north as Lithuania. From Poland they penetrated into Germany, reaching Silesia and Saxony (route 2) in late August. Eggs were laid in Saxony, where hoppers appeared in spring 1543, in the summer of which another wave spread along route 2 into Poland, Silesia and Saxony, while in the south swarms from Rumania penetrated along route 3 into Hungary, Austria and Tyrol. In 1544 swarms in western Russia reached as far north as the former Vitebsk Province (55–56°N.) and were reported in many parts of Germany, Austria and Tyrol, whence they spread into Switzerland in 1545. In Germany they survived till 1546 and in Switzerland till 1547 (Dalla-Torre, 1920 ; Keferstein, 1843 ; Keppen, 1870 ; Perlick, 1931 ; Rudy, 1925 ; Weidner, 1938 ; Zacher, 1917).

17th Century.

1680–1686. During this period there was a plague in central and north-eastern Europe. In 1680 locusts appeared in Saxony, and in 1681 in Poland, whence swarms penetrated to Mark Brandenburg ; in 1682 there was a plague in Hungary ; in 1683 again in Saxony ; by 1685 they spread from Hungary into Austria and Bohemia, while they persisted in Germany till 1686 (Filipjev, 1926 ; Keferstein, 1843 ; Keppen, 1870 ; Weidner, 1938*a* ; and Zacher, 1917). The source of the invasion is indefinite, owing to the incompleteness of records, though the outbreak in Hungary may have been of local origin.

1689–1696. The invasion of Ukraine, Western Russia and Poland in 1689–1691 indicated that the building up of swarms was taking place in the West Pontian area. In 1693 locusts were present in Poland, and a plague of them appeared in Hungary. According to Keferstein (1843) it was thought to have come from "Turkey," and this suggests that they came there, along route 3, from the lower Danube outbreak area. On the 3rd August locusts invaded Austria from Hungary. Here they separated into two waves, one of which invaded Bohemia, Saxony and Thuringia (route 3*a*), reaching Jena on the 18th August ; the other wave flew into Tyrol and Switzerland (route 3*b*). Silesia was invaded in early September, either from Bohemia, or from Poland (route 2). Egg-laying was recorded in Austrian Tyrol, where hoppers appeared in May 1694, and the locusts also became temporarily established in central Germany, where they were still present in 1695 and 1696 (Dalla-Torre, 1920 ; Keferstein, 1843 ; Keppen, 1870 ; Perlick, 1931 ; Rudy, 1925 ; Zacher, 1917).

* The British Isles were reached by locusts in 1693, for about the 20th October numerous locusts were seen scattered on the fields of Marthery Parish, Pembrokeshire, South Wales, and " two vast swarms " were seen flying near Dol-Gelbeu, Merionethshire, North Wales (Floyd, 1694).

18th Century.

1708–1715. In 1708 swarms, evidently originating in the West Pontian outbreak areas, invaded Wallachia, Moldavia, Transylvannia, Ukraine and Poland. The plague in Rumania persisted till 1712. In 1711 it extended northward to Lithuania (routes 1 or 2) and westwards into Hungary (route 3). In 1712 Silesia was invaded, apparently via southern Poland (route 2). The locusts became temporarily established in eastern Germany, where they were reported again in 1714 and 1715 (Knechtel, 1938 ; Keppen, 1870 ; Perlick, 1931 ; Zacher, 1917).

1719. Another recrudescence of swarms must have occurred in the West Pontian areas in this year, for locusts were again reported in Wallachia, Ukraine, southern Poland, Germany and Hungary (Keppen, 1870 ; Zacher, 1917).

1726–1732. In 1726 locusts from the West Pontian outbreak areas invaded Wallachia and spread along route 2 into southern Poland and Silesia where hoppers hatched round Breslau in June 1727. In that year locusts were again reported in Poland and Silesia, as well as in Hungary (route 3). In the next two years, the plague, consisting either of the progeny of the original swarms invading Silesia, where hoppers appeared again in 1728, or of new swarms from the south-east, spread to Saxony and Mark Brandenburg. Locusts became temporarily established in central and north-eastern Germany, for in 1730 hoppers and swarms appeared in the neighbourhood of Berlin ; egg-laying was reported in some parts of Saxony and Mark Brandenburg in 1731 and hoppers reappeared there in 1732 (Keppen, 1870 ; Weidlero, 1733–34).

1745–1754. In the middle forties, the outbreak areas of the West Pontian group began to function again, for in 1745 and 1746 swarms appeared in " southern Russia " (Keppen, 1870). In 1747 large scale breeding took place in the Danube delta and in Wallachia, Moldavia and Ukraine. From Rumania swarms moved along route 3 across Transylvannia into Hungary. In north-western Europe some stragglers were taken in Upsala, eastern Sweden (Boheman, 1847 ; Knechtel, 1938 ; Keppen, 1870 ; Perlick, 1931 ; Rathlef, 1748–1750 ; Zacher, 1917). In 1748 the plague spread along all the three routes and reached its greatest extent. In Rumania it was recorded in the Danube delta, Moldavia and Transylvannia, where hoppers hatched in May and adults appeared in June ; in Russia, in Ukraine, whence it spread into western Russia as far north as Smolensk Province and north-westwards to Vilno district, Lithuania. Swarms flying along route 2 invaded Volhynia and Galicia (southern Poland) in mid-July and subsequently reached Warsaw. In early August they reached Silesia, from whence they spread to Saxony. In Hungary hoppers hatched in early June, and the adult stage was reached in early July, when the new swarms moved westwards along route 3 into Austria and Bohemia. In Germany, Bavaria and the Palatinate were invaded, apparently from Bohemia. By mid-August swarms reached north-western Germany, where one was seen at Bremen on the 16th ; more swarms were seen there on the 30th August and the 8th September, and scattered individuals were numerous on the coastal plain. On 17th September some stragglers were seen at Hamburg, and in the same autumn stragglers were seen in Holland, south-eastern Sweden and in France. In Germany oviposition was recorded in Silesia, where owing to exceptionally warm weather hoppers hatched already in the autumn and must have perished (Fruhstorfer, 1921 ; Knechtel, 1938 ; Keppen, 1870 ; Rathlef, 1748–50 ; Rudy, 1925 ; Shaw, 1806 ; Wahlberg, 1846 ; Weidner, 1938 ; Zacher, 1917).

* In 1748 there was a considerable incursion into the British Isles (fig. 2, map II). In early August locusts were reported in Edinburgh, and by the 20th August in Staffordshire " where they were so numerous that they ate up all the green things," Cheshire, Derbyshire, Norfolk and in London, which was reached by several swarmlets after a great storm. Some stragglers were also seen in Rochester (Kent), Sussex and in Moray district, Scotland. By early September locusts were reported from many parts of Ireland, where great multitudes came to Dublin with an easterly wind, and by October they appeared in the Orkneys (British Isles, 1857 ; Couch, 1847 ; Donovan, 1799 ; Keppen, 1870 ; Rathlef, 1748–50 ; Shaw, 1806). According

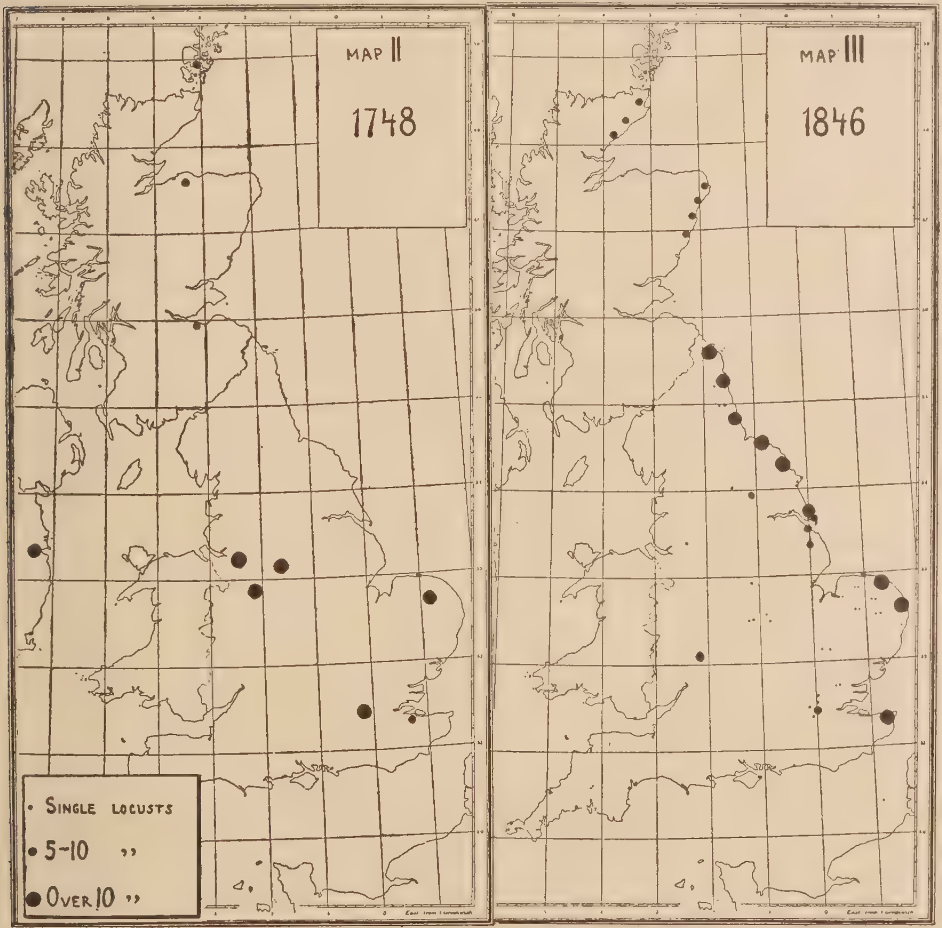

Fig. 2. Maps showing occurrences of *L. m. migratoria* in the British Isles in August–September 1748 and 1846.

to Rathlef, the locusts came to the British Isles with the east wind, which predominated during the exceptionally hot summer of 1748. It is not possible to conclude from the available data whether there was only one incursion of locusts, which gradually spread over the British Isles, or several.

In 1749 the outbreak continued in the Danube delta, Wallachia, southern Poland, Hungary and Bohemia. In late August swarms from Poland invaded Silesia, and probably Mark Brandenburg, where hoppers were recorded in subsequent years, while huge swarms, probably from Bohemia, invaded Bavaria. Some swarms again reached north-western Germany. Eggs were laid in many parts of Bavaria and hatched in spring 1750, but this generation perished owing to unfavourable climatic conditions. In 1750 locusts were recorded in Brandenburg, where they continued to breed until 1754 (Fruhstorfer, 1921 ; Keferstein, 1843 ; Keppen, 1870 ; Perlick, 1931 ; Rudy, 1925 ; Weidner, 1938 ; Zacher, 1917).

1756–1759. A recrudescence of the plague apparently occurred in the West Pontian outbreak areas in the fifties, for locusts were reported in Ukraine in 1756 and 1757 and in Germany in 1759 (Keppen, 1870 ; Zacher, 1917).

1780–1806. After an interval of about twenty years breeding up of swarms recommenced in the outbreak areas of the West Pontian group. In 1780 locusts were very numerous in Transylvania and in Bukovina (Rumania), and in the former Kherson Province in southern Ukraine (Keppen, 1870). A record made in 1788 states that " every year swarms appear in Moldavia and Wallachia " (Knechtel, 1938). The West Pontian outbreak areas continued to function throughout the last decade of the 18th century, for locusts were again present in the former Kherson Province in 1793 and 1794, and in Bessarabia in 1796 and 1797 (Keppen, 1870).

* In 1799 a straggler was found in England near Packington, Warwickshire (Donovan, 1799).

19th Century.

From 1799 the infestation in the former Kherson Province became intensified, and by 1802 the locusts spread further north into Ukraine and westwards into southern Poland. In 1803 Kursk and Orel Provinces were reached in the north and Galicia and Silesia in the west ; some stragglers reached Mark Brandenburg. In 1804 locusts, which were either the progeny of the 1803 invasion or came from the south-east, were again reported in eastern Germany, while in Poland and Ukraine the plague continued until 1806 (Kaminski, 1938 ; Keppen, 1870 ; Zacher, 1917).

1811–1818. During this period locust plagues occurred almost every year in Ukraine and southern Poland (Kaminski, 1938 ; Keppen, 1870). Their origin is not definite, but was probably the West Pontian area. In Germany single stragglers were taken near Nürnberg, Bavaria, in 1811 and at Ditmarsh, near the mouth of the Elbe, in 1814 (Germany, 1848 ; Zacher, 1917).

1821–1836. This outbreak undoubtedly originated in the West Pontian areas. From 1821 locusts were reported in the former Kherson Government and in Bessarabia, by 1824 they had invaded the greater part of Ukraine and southern Poland, as far west as Lwow (route 2) and in 1825 spread into Silesia and Mark Brandenburg. In March 1826 the progeny of the invading swarms hatched in Mark Brandenburg, and that area and Silesia were again invaded by swarms from the east in July (Keferstein, 1843 ; Keppen, 1870 ; Zacher, 1917).

* In July 1826 a specimen was taken in Clapham Road, London (Curtis, 1936). It may have been a straggler from the swarms migrating at that time into eastern Germany, or alternatively one of the locusts which hatched in Mark Brandenburg in March and would have become adult by July. The four British specimens now in the Hope collection, University Museum, Oxford, without localities and labelled " migratoria Inst'd 1826 " (see Table VII) may have been taken in 1826. They belong to phases *gregaria* and *transiens*, and must have been stragglers from swarms.

In 1827 swarms from western Russia or Poland reached northwards to the Lithuanian border; swarms were again present in Silesia and Mark Brandenburg, where hoppers hatched in spring throughout the area from Jutenborg in the west to the Pomeranian border and beyond into Birnbaum in the east. In Ukraine and southern Poland locusts were still numerous in 1828, but almost disappeared by 1830. In the Danube delta production of swarms had probably gone on all the time, and after the invasion had died down elsewhere swarms from the delta continued to invade Bessarabia until 1836 (Keferstein, 1843; Keppen, 1870; Zacher, 1917). A stray specimen was taken in Sweden in 1834 (Wahlberg, 1846).

* In 1836 a straggler was found in Waterford, south-eastern Ireland (Curtis, 1836).

1842–1850. From the early forties the locusts began breeding up in the West Pontian outbreak areas, as is shown by the appearance of swarms in southern Ukraine in 1844 (Keppen, 1870).

* It appears that even before the emigration of large swarms, small swarms and separate individuals were already leaving the outbreak areas. In September 1842, there was a small influx of locusts into Yorkshire, whence they spread further inland. During the first ten days of the month two specimens were taken in Scarborough, several near the coast in Holderness and one at Mickleover, Derbyshire. By mid-September isolated specimens were taken in Leeds, Sheffield, Chesterfield (Derbyshire) and Burton-on-Trent (Staffordshire), and three more at Scarborough (Brown, 1842; Denny, 1842; Roebuck, 1877).

In the middle of September 1843 numerous locusts were seen flying over Braviken, Ostergötland, south-eastern Sweden, in a north-westerly direction (Bohemann, 1844; Wahlberg, 1846). In 1844 a straggler was taken on Ostsee beach, near the mouth of the Elbe (Germany, 1848). In 1845 locusts were numerous in southern Ukraine, and Bessarabia was invaded by swarms from the Danube delta, while scattered individuals were found throughout central Germany from Silesia to Trèves (Keppen, 1870). In 1846 in July huge swarms from the Danube delta invaded Bessarabia and the former Kherson Province, southern Ukraine and spread to Moldavia, Wallachia and Bukovina. The locusts also penetrated to Silesia where much damage was done near Breslau. During late summer scattered individuals were recorded in Germany from Saxony, Hessen-Nassau, Baden, Holstein and Fohr Islands, to the west of Schleswig. From mid-August swarmlets and scattered individuals were seen in Malmohüs and Christianstad, in the extreme south of Sweden, and in September a straggler was taken in Holland (Boheman, 1847; Germany, 1848; Keppen, 1870; Perlick, 1931; Rudy, 1925; Wahlberg, 1846; Weidner, 1938*a*; Willemse, 1917; Zacher, 1917).

* In 1846 there were several incursions of locusts into the British Isles, most of which struck the eastern seaboard, though some reached the southern coasts (fig. 2, map II). Early in August a locust was taken at Flamborough, and during the second week of the month a " large flight " was observed in Sunderland, hovering near Hendon and then flying south. By the end of the month more locusts were seen in East Riding and one at Bembridge, Isle of Wight. In Scotland numerous locusts were seen along the coast of Aberdeen and Kincardine in August and September, and some in Sutherland and further north. In early September locusts were taken in Manchester, at Louth, Lincs., in many parts of London and at East Looe and Land's End in Cornwall. It is probable that undated records from St. Just and Penzance (Cornwall) and Dawlish and Exmouth (South Devon) were made about this time. More stragglers and swarmlets must have reached the eastern coasts of England in September, for locusts were again taken on Holderness, in and near York and at Marsden and Newcastle-on-Tyne; whole flights were seen near Cromer and Yarmouth and numerous individuals in inland parts of Norfolk; a couple at Chelmsford (Essex) and many along the Kent coast at Margate; one was taken at Littlehampton

(Sussex). On the 25th September the "Hull Packet" reported that the whole coast between the Humber and Tweed was being subjected to inroads of locusts. A few days before, a cloud settled near Spurn Point where masses of dead locusts were seen on the 29th. Undated records from Cambridgeshire, Nottinghamshire, Rutland, Leicestershire, Worcestershire and Nash Lighthouse, Glamorganshire, show that the locusts spread far inland and penetrated to South Wales (British Isles, 1857; Clark, 1907; Couch, 1847; Evans, 1901; Roebuck, 1877; Spence, 1847). Four specimens taken in 1846 are available for study (see Table VII). They belong to phases *gregaria* and *transiens* approaching *gregaria*, and prove that the incursions into British Isles consisted of parts of migrating swarms.

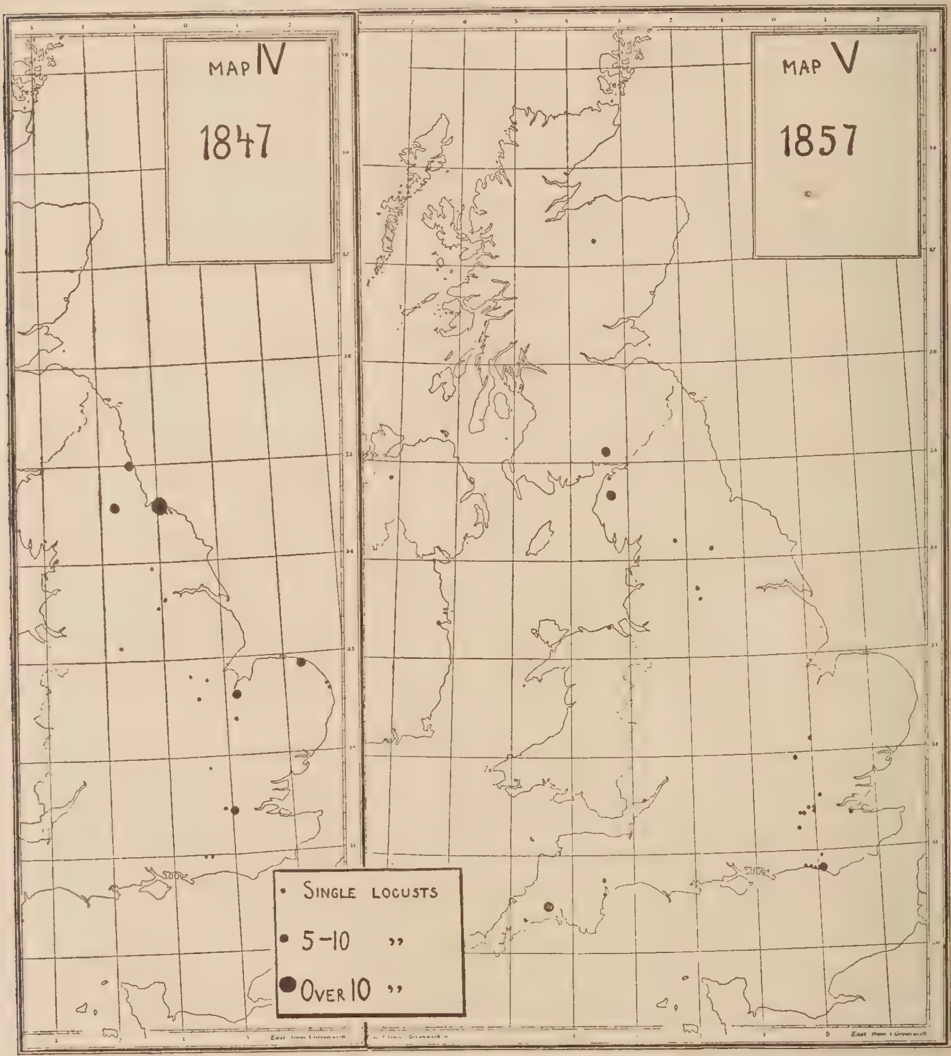

Fig. 3. Maps showing occurrences of *L. m. migratoria* in the British Isles in August–September 1847 and 1857.

In 1847 masses of hoppers hatched in Bessarabia and the former Kherson Province of Ukraine, and swarms again overran southern Ukraine, Moldavia and Transylvania, and penetrated into Silesia. Scattered locusts were seen in Westphalia, in Baden, in Holstein and on Föhr Islands (in August). In late August a straggler was caught in southern Sweden, and in September several specimens were taken in Cherbourg, north-western France, and one in Amsterdam (Boheman, 1847; Germany, 1848; Gadeau de Kerville, 1932; Keppen, 1870; Perlick, 1931; Rudy, 1925; Willemse, 1917).

* The 1847 invasion of England was on a smaller scale than the preceding one (fig. 3, map IV). About the 19th August a swarmlet must have reached the coast of North Riding, for on that date many drowned locusts were seen on the beach and live ones on the sandhills of Redcar. On the 26th a straggler was captured near York, and in early September three at Thorne and one near Doncaster, West Riding, so that locusts were spreading inland. Undated specimens were reported from Durham, Lincolnshire, the Norfolk coast, Cambridgeshire, Hertfordshire, Middlesex, London and Sussex. Further west single locusts were caught on Elton Moor, Derbyshire, and at Sunderland Point, Lancashire (Anonymous, 1930; Roebuck, 1877). It appears that eastern England was again subjected to several incursions. Three specimens taken in 1847 are available for study (see Table VII). They all belong to ph. *gregaria* and were again derived from migrating swarms.

In 1848 the outbreak was still continuing in southern Russia. In north-western Europe stragglers were recorded from Baden, Westphalia and Hanover in Germany, from Holland, and from Gotland Island in the southern Baltic (Ander, 1931; Germany, 1848; Keppen, 1870; Rudy, 1925).

* In England they were plentiful on the north Kentish coast, at Herne Bay (Roebuck, 1877).

During the next two years, while the locusts in the outbreak areas must have been reverting to the solitary phase, stragglers continued to reach western Europe. In 1849 some were taken in Hessen Nassau in Germany, at Als in Denmark, and in Amsterdam (Henriksen, 1939; Keppen, 1870; Rudy, 1825; Willemse, 1917).

* In England a straggler was caught at Thirsk, Yorkshire, in 1849 (Roebuck, 1877) and one at Ipswich, Suffolk, in 1850. This specimen has been preserved (see Table VII) and belongs to ph. *transiens*.

1853–1865. Some locusts were recorded in Silesia and Mark Brandenburg in 1853. These were probably immigrants from the West Pontian outbreak areas, where breeding up of swarms must have been taking place at that time, for in 1854 a plague of them appeared in south-western Ukraine. In 1855 it spread also to Bessarabia and Dobrudja (Rumania) (Keppen, 1870). The outbreak continued in 1856 and in 1857; in 1856 some swarms reached north to Orel Province in central Russia.

* In 1857 occurred a widespread incursion of locusts into the British Isles (fig. 3, map V). During the second week in August a locust was caught in London, and on the 19th at Achvokie, Strathspey, Scotland. Some days later other locusts were caught in Yorkshire, Suffolk, Hertfordshire, again in London, and on Chatham Marsh in Kent; about the same time a specimen was taken in Tyrone, Northern Ireland. Thus, except for the Irish record, the locusts taken in August had an easterly distribution. In early September a specimen was caught in Surrey, three at Newhaven, Sussex, and in north-west Cumberland and near Dumfries, Scotland. In mid-September some were taken at Kingston-on-Thames, at Hove, near Brighton, at Chepstow, Monmouthshire, and at Rhyl, North Wales. One was taken at Halifax, Yorkshire, some time in September. There were undated records from Sussex, London, Essex, South Devon and Cornwall, and from "Solway" and Dublin (British Isles, 1857; Clark, 1907; Parfitt, 1882; Roebuck, 1877; the *Dumfries Courier*, September

1857). According to Roebuck several hundreds of specimens appear to have been captured and many more undoubtedly escaped notice, but unfortunately no details were published about most of them, and from the available records it is impossible to reconstruct the course of the invasion which spread throughout the British Isles. Of the five specimens preserved from this invasion (see Table VII) four belong to ph. *transiens* and one to ph. *gregaria*.

In 1858 the plague spread throughout southern Ukraine and continued in Bessarabia. Stragglers were seen on the Friesian Islands (off Hanover) and in late September and October at Charlottenlund and Copenhagen, Denmark (Henriksen, 1939; Keppen, 1870; Weidner, 1938; Zacher, 1917).

* In the British Isles great numbers of locusts occurred in September 1858 on Lerwick and all other Shetland Islands, as far north as Unst. Many were also taken in Caithness, where they were so numerous as to amount to a positive plague (British Isles, 1858). A female taken that year on the Shetlands (see Table VII) belongs to ph. *gregaria*. Further south, locusts were " plentiful " near Hull (Roebuck, 1877).

In 1859 swarms spread throughout western and southern Ukraine and over Rumania. It is possible that the invasion of Ukraine was partly due to immigration from the East Pontian areas, where an outbreak was in progress since 1856 (Nikolsky, 1925). In July swarms from Bessarabia and former Kherson Province moved along route 2 into Podolia and in August spread to Galicia in southern Poland, and from there north-westwards to Tempelburg in Pomerania (Kaminsky, 1938; Knechtel, 1938; Keppen, 1870; Nikolsky, 1925; Zacher, 1917). In the same summer stragglers were seen in Germany in Hessen Nassau, in Wurtemberg (August), at Haarlem, Noordwijk and Rotterdam in western Holland, and in most provinces of Belgium (Rudy, 1925; Selys Longchamps, 1862; Willemse, 1929).

* In England a straggler was caught at Portsmouth on the 14th July, that is at the time when swarms were moving into Poland along route 2. During the first half of September, single specimens were taken at Herne Bay, Kent, at Wallingford, Berkshire, at Glanwootton, Dorset, and ten near Northampton. Several specimens were again captured near Hull (Roebuck, 1877). The distribution in 1859 was generally southerly and easterly. The Dorset specimen has been preserved (see Table VII) and belongs to ph. *gregaria*.

In 1860 there was extensive hatching in previously invaded areas of southern Russia; the swarms occupied most of Ukraine and Bessarabia and spread into southern Poland in August; Warsaw was reached in early October (Knechtel, 1938; Keppen, 1870).

* In the British Isles in 1860 two specimens were caught at St. Mary, Scilly Islands (Clark, 1907).

In 1861 the intensity of the outbreak declined in Ukraine and Bessarabia, but the swarms reached northwards to Orel and Moghilev districts in central and western Russia, while in Poland a swarm reached Suvalki, on the Lithuanian border. Stragglers were found in Hessen Nassau and in the Main valley in Germany and in Belgium (in October) (Keppen, 1870; Rudy, 1925; Selys Longchamps, 1862). In 1862 the plague declined in Ukraine, but in Rumania the outbreak area in the Danube delta continued to function in 1863, 1864 and 1865, sending out swarms into adjoining areas (Knechtel, 1938; Keppen, 1870; Nikolsky, 1925).

* In September 1864 numerous locusts appeared on the coast of Cornwall (Newman, 1870; Roebuck, 1877), and a straggler was taken at Stowmarket, Suffolk, in 1867 (Anonymous, 1930).

1866–1881. Throughout this period the West Pontian outbreak areas appear to have been quiescent. Further east there was an outbreak in Daghestan (the Caspian group) in 1869 (Nikolsky, 1925).

* In autumn 1869 large numbers of *Locusta* invaded the county of Aberdeen, occurring all along the coast and westwards to Balmoral (Angus, 1870 ; Roebuck, 1877). Their origin is problematical. In August of the same year great numbers of *Schistocerca gregaria*, Forsk., coming from the African continent, appeared all along the south coast of Devon and Cornwall from Plymouth to Penzance. From there they spread north and east, and were recorded in Worcestershire, Warwickshire, Derbyshire, Staffordshire, Nottinghamshire and in County Waterford, south-eastern Ireland (Parfitt, 1882 ; Roebuck, 1877). Unidentified locusts taken in Richmond, Surrey, and near Halifax, Yorkshire (Anonymous, 1870 ; Roebuck, 1877), probably belonged to this species.

In the Kuban (East Pontian group) there was an outbreak between 1873 and 1877, and again in 1879 to 1884 ; the outbreak areas of the Caspian group began to function again in 1879 and continued to do so intermittently till the end of the century (Nikolsky, 1925). During this period *Locusta* was recorded in several parts of Germany. In 1870 it appeared as a plague in Mark Brandenburg (Zacher, 1917). From 1873 to 1875 they did considerable damage to crops near Magdeburg in Saxony (Weidner, 1938a) ; in 1874 to 1879 they were recorded as a plague in central and north-western Mark Brandenburg and in Mecklenburg, and in 1875 in western Prussia (La Baume, 1920 ; Zacher, 1917) ; they were frequently seen in the Rhineland and Westphalia between 1775 and 1880 (Rudy, 1925 ; Zacher, 1917), and in 1876 and 1878 on Lüneburger Heide, Hanover (Weidner, 1938). These appearances may have been due to relative increases in the numbers of indigenous locusts (see p. 214), but in view of contemporary outbreaks in the East Pontian areas, the possibility of immigration from the east cannot be entirely ruled out.

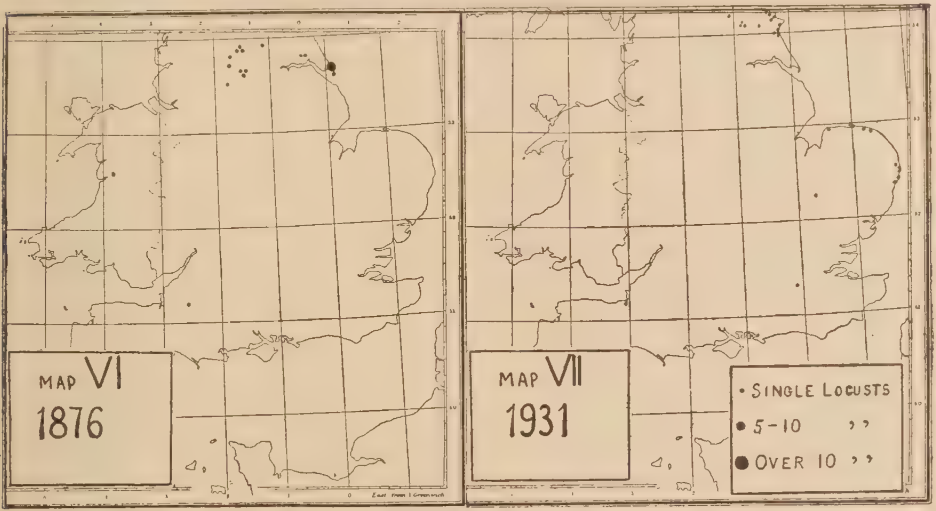

Fig. 4. Maps showing occurrences of *L. m. migratoria* in the British Isles in August–September, 1876 and 1931.

* In summer 1874 large numbers of locusts appeared near Cheddar village in Somerset and did much damage (Roebuck, 1877). It is not definitely known that they were *Locusta*, and may have belonged to a different species. In 1875 some locusts were taken in Yorkshire. On the 5th July two were picked up in Sheffield. Their remarkably early occurrence suggests that they must have come from central or northern Germany. On the 11th September a specimen was collected near Brighouse, West Riding ; two undated specimens were collected at Easington,

near Spurn Head (Roebuck, 1877). In 1876 there was a larger incursion, but it was again almost confined to Yorkshire (fig. 4 map VI). In the second half of August two specimens were taken at Beverley, East Riding, and during the last ten days of the month several were caught in Leeds, one near Halifax and two in Wakefield, all in West Riding. In early September single specimens were taken on Spurn Head, near York, at Scarborough and at Wakefield ; about the middle of the month one was again taken at Leeds and eight at Easington, near Spurn ; on the 27th one at Huddersfield. Undated specimens were taken near Machynlleth in North Wales, and in Wells, Somerset (Clark, 1907 ; Roebuck, 1877).

* In 1879 several specimens of locusts were taken at the Lizard, Cornwall (Clark, 1907). In 1880 there was an incursion into Scotland, in late August a straggler was caught near Wick, Caithness, and two at Lamberton, Berwick. On the 7th September, one was taken near Edinburgh, and towards the end of the month single specimens were taken near Kelso and at Harwick, Roxburgh. In the same month a specimen was caught at South Ronaldshay, Orkneys (Evans, 1901).

It appears very probable that the incursions into Yorkshire in 1875 and 1876 came from Germany. The origin of 1879 and 1880 invaders is more problematical ; it is quite possible that they came from the West Pontian outbreak areas where building up of swarms may have already begun by that time (see next paragraph).

1882–1889. Extensive egg-laying in the reed-beds of the lower Dniestr and Dniepr (southern Ukraine) was reported in the autumn 1882 (Nikolsky, 1925) ; in the same year several stragglers were caught in Estonia (Zolk, 1934). In 1883 began an outbreak in the Danube delta (Nikolsky, 1925). A plague of locusts recorded in Brandenburg (Zacher, 1917) may have been due to immigration from the West Pontian areas. The outbreak continued in these areas in 1884, in which stragglers were observed near Riga, Latvia (Princis, 1932) and in many parts of Denmark (Henriksen, 1939). By 1886 the outbreak apparently died down in the reed-beds of the Dniestr and Dniepr, but south-western Ukraine was re-invaded by swarms from Bessarabia (Nikolsky, 1925).

* In 1886 a straggler was taken near Louth, Lincolnshire, in mid-October (Shaw, 1886).

The outbreak in the Danube delta reached its maximum in 1887, and continued till 1889 (Knechtel, 1938 ; Nikolsky, 1925) ; in 1888 a locust was taken at Voerbane, Denmark (Henriksen, 1939), and in that year and in 1889 swarmlets, which may have migrated from the delta along route 3, appeared in eastern Hungary (Jablonowsky, 1926).

* In 1889 two locusts were taken near Penzance, Cornwall (Clark, 1907).

1893–1894. During this period there was an outbreak in the Danube delta (Knechtel, 1938 ; Nikolsky, 1925), when only the immediately adjoining areas were affected.

1895–1898. * During these years while the West Pontian outbreak areas were in a quiescent state, isolated individuals were taken in the British Isles in 1897 and 1898. In the first year two were caught at Harleston, Norfolk, one at Longhaven, Aberdeen, and two in Penzance (Anonymous, 1930 ; Clark, 1907 ; Evans, 1901). One of the Harleston specimens has been preserved and belongs to ph. *transiens* (see Table VII).

* In August 1898 a female was taken at Gorleston, Norfolk ; and another one (undated) on the lighthouse, South Aran Island, Western Ireland. Both these are available for study, and are of special interest, for they are exceptionally large and definitely belong to ph. *solitaria* (see Table VII and p. 239).

20th Century.

1899–1902. During this period swarms were present in the Danube delta (Knechtel, 1938). In 1899 a straggler was found in Amsterdam, Holland (Willemse, 1917).

* On the 30th August 1899 a large female was taken on the Calf of Man, south of the Isle of Man (see Table VII). The specimen belongs to ph. *transiens* and indicates that phase transformation was taking place in the outbreak area. In 1901 a straggler was caught at Moulscombe, near Brighton (letter to Dr. Uvarov from A. F. Brazenor), and in 1902 one was taken at St. Agnes, Scilly (Clark, 1907).

1906–1912. In these years there was again a small outbreak in the Danube delta (Knechtel, 1938 ; Vereschagin, 1913). In the first year swarms may have reached Bulgaria, where there was a mass appearance of locusts, which were probably *Locusta* (Tchorbadjiev, 1936) and a specimen was taken at Bremen (Weidner, 1938) ; in 1907 some were caught in Holland (Willemse, 1929).

* In 1906 a straggler was taken at Godolphin, Cornwall (Clark, 1907), and in August 1908 a specimen was caught on Brighton Downs, Sussex (letter to Dr. Uvarov from A. F. Brazenor).

The outbreak area in the Danube delta continued to function until 1912 (Knechtel, 1938), when locusts appeared along the lower Dniepr, southern Ukraine (Nikolsky, 1925). In the same year stragglers were seen near Libau, in Latvia (Princis, 1932), and on the Island of Oesel, off Estonia (Zolk, 1934), and between July and September numerous specimens were observed on the east coast of Sweden and the south coast of Finland (Frey, 1937 ; Kivirikko, 1913 ; Tullgren, 1913).

1919–1924. After 1912 the West Pontian outbreak areas were quiescent for some years. The building up of swarms probably began there in 1919, for between 1919 and 1921 there was an outbreak in eastern Rumelia, Bulgaria, which in former years had been frequently invaded from the Danube delta (Tchorbadjiev, 1936). In 1921 stragglers were observed in Groningen Province, Holland, near Hamburg in Germany, and one on the 15th September at Bueil, Normandy (Chopard, 1932 ; Weidner, 1938 ; Willemse, 1929).

* In 1921 two stragglers were taken in England, one on the 9th September on Southwold Common, Suffolk (Collings, 1932) and one on the 11th October in Chelsea, London (see Table VII). This specimen belongs to ph. *transiens*, so that phase transformation must have been occurring in the outbreak area.

This process continued in the following years, and in 1923 and 1924 there was an outbreak in the Danube delta (Knechtel, 1938). In the latter year masses of locusts appeared in eastern Hungary (Jablonowsky, 1926), which was probably reached by route 3.

1927–1933. After two quiet years locusts began to swarm in the Danube delta in 1927, the outbreak continuing till 1933 (Knechtel, 1938).

* In 1929 stragglers were taken in England, one in September at Sittingbourne, Kent (letter to Dr. Uvarov from F. D. Welch) and a ph. *gregaria* female at Stratford-on-Avon in October (Table VII).

In 1930 the swarms spread from the Danube delta into Bessarabia (Vereschagin, 1931). In the same year stragglers were seen in Estonia (Zolk, 1934) and after a violent storm in mid-August numerous locusts reached the Finnish coast between Hangö and Helsingfors (Frey, 1931). In 1931 swarms from the delta again invaded southern Bessarabia.

* In 1931 considerable numbers of scattered locusts reached eastern England (fig. 4, map VII). Some were taken on the 6th August at Bridlington, East Riding. During the second half of August isolated specimens were taken at several points on the coast of Norfolk. In early September locusts were collected in a number of

localities on the Yorkshire coast, and one was taken at Leatherhead, Surrey. About the middle of September more specimens were caught in different parts of Yorkshire and in Norfolk, towards the end of the month still more in Yorkshire and one on the Southwold Common, Suffolk. One specimen was taken at Bradwell, Suffolk, as late as the 1st October. Undated specimens were recorded from parts of Yorkshire, Norfolk and Suffolk (Anonymous, 1931 ; Clark, 1931 ; Collings, 1932 ; Walsh, 1931 ; John Knowlittle, in the *Eastern Daily Press*, 9.ix.31 ; *Hull Times*, 26.xii.31 ; letters to the British Museum from L. C. Bushby, R. M. Garnett, D. H. St. Quentin, A. K. Patterson, P. E. Rumbelow, and H. W. Weddel). All the records were confined to eastern counties, which may have been subjected to more than one incursion. Some of the immigrants taken that year have been preserved (see Table VII), and all belong to ph. *gregaria*.

1934–1939. *Since the dying down of the last outbreak in the Danube delta locusts have reached the British Isles on several occasions. In 1936 one was found at Broxbourne (Hertfordshire), two near Saint Andrews, Fifeshire, and one at Helmsdale, Sutherland (*Gardener's Chronicle*, 20.x.36). In 1938 single specimens were taken on Holy Island, off Northumberland, in August and at Pottersbury, Northamptonshire, and on Rousey Island, Orkneys, in September (Waterston, 1939, and Table VII). All three are especially large ; one is a typical ph. *solitaria*, while the others belong to ph. *transiens*. At that time phase transformation into ph. *gregaria* was taking place in Rumania, for phases *transiens* and *gregaria* were collected there in 1938 and 1939 (see Table VI). The two specimens caught on 12th September 1939 in North Ronaldshay, Orkneys, and on the 15th September 1939 on North Mavine, Shetlands (see Table VII) belonged respectively to ph. *transiens* and ph. *gregaria*.

Discussion of European Invasions.

The preceding survey shows that in former centuries invasions of *Locusta migratoria migratoria* originating in the West Pontian outbreak areas spread in Europe over huge areas. For instance, in 1693 swarms emigrating from there reached Wales (a distance of about 1,600 miles along a straight line) ; in 1748 swarms which left Hungary or the West Pontian region in July reached north-western Germany by mid-August. Such distances, covered within the migration period of a single generation, are comparable to those traversed in Africa by *Locusta migratoria migratorioides* (R. & F.), swarms of which migrated in 1930 from Nigeria eastwards almost to the Abyssinian border, and again in 1931 from Tanganyika Territory diagonally across the continent into Angola and South-West Africa, about 1,500 miles in a straight line (Great Britain, 1937). It appears, therefore, that the phenomenon of migration of locusts over thousands of miles is not confined to the tropics, but occurs also in the temperate belt. It is not known whether such distances are traversed in a single flight or by successive stages.

Such cases, however, were exceptional, and as a rule large swarms did not penetrate beyond central Europe. Small groups and separate individuals, however, had migrated, and continue to migrate, over greater distances. In 1836, for instance, when there were no swarms anywhere except in the Danube delta and Bessarabia, one individual migrated for about 1,700 miles to south-eastern Ireland ; in 1858 when swarms were confined to Ukraine and Bessarabia, numerous individuals reached the Shetlands about 1,600 miles away. Such examples can be multiplied, and concern not only the migrants of ph. *gregaria*, but also of ph. *solitaria*.

The swarms emigrating from West Pontian outbreak areas often found suitable secondary breeding areas in the steppes of Ukraine, Rumania, southern Poland and Hungary, from which their progeny could invade the surrounding areas. For instance, swarms which penetrated into Austria and Bohemia in 1748 were the progeny of those invading Hungary in 1747 ; eastern Germany was in 1728, 1749, 1804 and 1825–

1826 invaded by swarms, which were at least partly the progeny of swarms invading Poland in the preceding seasons. Such an extension of the invaded area by successive generations is to some extent analogous to this process in Africa, where between 1928 and 1930 the whole tropical belt north of the equator was overrun by five successive generations of *Locusta migratoria migratorioides* (Great Britain, 1937), though in temperate Europe it is slower, as only one generation is produced in a year.

The decline of West Pontian outbreak areas is reflected in the gradual decrease of areas invaded by swarms. The last occasion on which large swarms reached Hungary, Austria and Bohemia, was during the 1745–1754 outbreak period ; eastern Germany was last invaded by large swarms from the West Pontian region in 1842–1850 period (except for small possible immigrations in 1853 and 1883) ; Poland was last reached in 1854–65 period. Since then the invasion area became restricted to Ukraine and Rumania, and after the dying out of the Ukrainian outbreak centres towards the end of the last century, to areas nearest the Danube delta (except for the invasion of the Dniepr reed-beds in 1912, and small invasions of eastern Hungary in 1924). It is significant, however, that in spite of the decrease in areas reached by swarms, small groups and individuals continue to migrate for long distances, and up to the present day these are to be found in northern and north-western Europe whenever there is an outbreak in the Danube delta, and undoubtedly also during the intervening periods.

The Phases of British Specimens.

The determination of the phases to which British specimens belong presented some difficulties, for a reliable biometrical study of the extreme phases in *L. m. migratoria* has not yet been made. Pure material of ph. *gregaria* can only be obtained from dense swarms invading a locality previously entirely free from this species, and of ph. *solitaria* from an area where no swarming ever occurs, and which had been free from invading swarms for several seasons. Gause (1928) in his study of variability in *L. migratoria* specified the phases to which his material belongs, but he used biometrical measurements differing from those subsequently recommended by Zolotarevsky (1933) and adopted by the Fourth International Locust Conference (Egypt, 1937), which were used in the present study. Makalovskaya's (1930) figures could not be used, as she attempted to work out the characteristics of phases on material from a swarm which apparently consisted of ph. *dissocians*.

TABLE VIII.

The ratios in L. m. migratoria *and in* Locusta *from Western Mediterranean region.*

	E/F Range	P/C Range	H/C Range	M/C Range
L. m. migratoria—				
Phasis *solitaria* (Turkestan ; Plotnikov, 1927)—				
Females	1·71–2·10			
Males	1·71–2·05			
Phasis *gregaria* (Stavropol Prov., 1912, Dr. Uvarov's measurements)—				
Females	2·15–2·38			
Males	2·07–2·21			
Western Mediterranean "race" of *L. migratoria* ph. *solitaria*—				
Females	1·65–2·01	1·41–1·65	1·26–1·61	·90–1·03
Males	1·67–1·91	1·37–1·71	1·27–1·50	·91–1·04

The tentative ranges of ratios of the two phases in *L. m. migratoria* are given in Table VIII. The range of E/F ratios for ph. *solitaria* was taken from figures quoted by Plotnikov (1927) for individuals with convex pronotal keels, collected by him as solitaries in different parts of Turkestan. The E/F ratios for ph. *gregaria* were obtained from measurements of locusts from dense swarms originating in the Terek valley, Daghestan, which in 1912 invaded parts of Stavropol Province, northern Caucasus, previously free from swarms (supplied by Dr. Uvarov). The ranges of ratios for ph. *solitaria* in the western Mediterranean "race," which are also included in the Table because they are the only related group for which ratios other than E/F could be calculated, were obtained from specimens in the British Museum, together with those quoted by Zolotarevsky (1933) for specimens from southern France, and Uvarov & Hamilton (1936) for Algerian specimens. The incomplete data in Table VIII are in general accord with the ratios for phases of *L. migratoria* given by Zolotarevsky (1933), *i.e.* :—

	E/F	P/C	H/C	M/C
ph. *gregaria*	equal to or greater than 2	about 1	about 1	0·6 to 0·8
ph. *solitaria*	less than 2	greater than 1	greater than 1	equal to or just below 1

With the help of these data the British specimens were provisionally divided into phases *solitaria, transiens* and *gregaria* ; in the separation of the last two the E/F ratio of 2·10 was taken as the approximate dividing value, but other ratios, and their relation to the ratios for ph. *solitaria* of the Western Mediterranean "race," were also taken into consideration. Definite determination will not be possible until the phase ratios for different races are worked out on sufficiently large and reliable material, and the degree of morphological modification accompanying phase transformation is established for different subspecies and races.

Discussion of British Invasions.

Only the winged adults of *Locusta* have ever been observed in this country, and as there is not a single record of hoppers, all the British records must refer to immigrants. In the middle Volga region, inhabited by *Locusta* approaching *L. m. migratoria*, sexual maturation is possible at average monthly temperatures of 22°C. for July and 19·3°C. for August (Zolotarev, 1936). Even in the warmest south-eastern part of England the average conditions are below these limits, but during exceptionally warm summers temperatures may be high enough for maturation to take place. For instance the mean July–August temperatures at Cambridge are just over 16°C., but the highest average monthly temperatures are over 19°C. ; for Greenwich the figures are 17°C. and over 20°C., respectively (Meteorological Office, 1923). Should the immigrants arrive during such an exceptionally hot July or August, they might become mature in this country ; those appearing in September may be already sexually mature. However, even if oviposition does take place, the eggs evidently perish, possibly owing to infection by fungous diseases, which would be favoured by humid and relatively mild winter conditions.

The locusts arriving in the British Isles may conceivably be derived from several sources. These will now be examined in turn :—

(1) *Western Mediterranean Area.*

Here the species often hibernates in the adult stage, which survives till next spring. Although conditions in spring and early summer often favour migration from the Mediterranean area to the British Isles, as is evidenced by the frequent immigration at that season of migrating species of Lepidoptera (*e.g.*, *Celerio lineata livornica*, Esp., *Plusia gamma*, L., *Vanessa cardui*, L.) probably originating in Africa (Grant, 1937 and 1938), *Locusta* has never been recorded in the British Isles earlier than July.

Moreover, the British specimens are biometrically distinct from the western Mediterranean "race" (see p. 220).

(2) *The Relict Areas of Northern and Central Europe.*

These are inhabited by *L. m. rossica* or "races" akin to it, which are biometrically distinct from British immigrants (see p. 220), and which have never been observed to undertake long migrations.

(3) *The West Pontian Outbreak Areas.*

The locusts found in the British Isles belong to the same subspecies, *L. m. migratoria,* which is found in the West Pontian area (see p. 223). They almost invariably arrive in August–September, *i.e.,* about a month after they had reached the adult stage in the West Pontian area. The exceptionally early immigrations in July, as in 1826 and 1859, in both cases occurred at the time of active migration of swarms from the West Pontian region into eastern Germany and into Poland, respectively (see pp. 228 and 232). The October records may refer to individuals which had reached this country at an earlier date. Most British records were made in the years when swarms were present in the West Pontian outbreak areas and stragglers reached other parts of north-western Europe, and the periods when locusts appeared in the British Isles for several consecutive years, as in 1846–1850, 1857–1859, coincide with lengthy outbreak periods in that area. The period 1874–1876 is exceptional, and these immigrations probably came from secondary breeding areas in Germany (see p. 234). Further evidence of the West Pontian origin of British specimens can be deduced from their phase characteristics. The locusts reaching this country during the 1842–1850, 1853–1865, 1927–1933 invasions belonged partly to ph. *transiens,* but predominantly ph. *gregaria,* and must have been detachments from swarms which were then emigrating from that area ; locusts reaching the British Isles while the West Pontian outbreak areas were quiescent (*e.g.,* in 1895–98), and the species surviving there as ph. *transiens* and ph. *solitaria* belonged to these phases. These considerations offer strong evidence that most of the locusts reaching the British Isles must be immigrants from the West Pontian outbreak areas.

The locusts migrating over a wide front over northern Europe in a general south-east to north-west direction may strike the British Isles in any part of the eastern sea-board or along the whole of it, as for instance in 1846. A frequent immigration route appears to be *via* Yorkshire and East Anglia. Thus the Yorkshire coasts were reached in 1842, 1846, 1847, 1849, 1858, 1859, 1875, 1876 and 1931, and the East Anglian in 1847, 1850, 1897, 1898, 1921 and 1931. Eastern Scotland and the islands lying to the north-east of Scotland are liable to quite frequent invasions (*e.g.,* in 1748, 1846, 1858, 1869, 1880, 1897, 1936, 1938 and 1939), and sometimes locusts reach these northern regions while the rest of the British Isles remains free (*e.g.,* in 1869 and 1939). Occasionally the incursions occur *via* the southern coast, *e.g.,* all along the south coast in 1846, Hampshire in 1859 ; Scilly Islands in 1860 ; Cornwall in 1864, 1879, 1897 and 1906 ; Sussex coast in 1901 and 1908. The points at which the British Isles are attained probably depend on the route followed over the continent and the distribution and extent of air currents with which the locusts are travelling. *L. m. migratoria* is not the only insect migrating in late summer to the British Isles from Europe, for incursions of some Lepidoptera also occur at that season. The European progeny of *Vanessa cardui,* L. (which in spring invades Europe, including the British Isles, probably from regions to the south of the sub-tropical desert belt) migrated in August 1879 from central Europe into north-western Europe and the British Isles. In 1903 swarms of this species were observed in Rumania and Hungary, and their progeny appeared in September in north-western France and in eastern England (Williams, 1930) ; the butterflies must have migrated along the route often followed by *Locusta.* Similarly in the case of the Silver-Y moth, *Plusia gamma,* L., which in spring invades Europe and the British Isles from the south, the European progeny sometimes migrate westwards to the British Isles in August–September, as in 1879, 1903 (Williams, 1930), and in 1933, 1934, 1935, 1936; in the last year the westward flight across the North Sea reached enormous proportions (Grant, 1938). It may be significant that in the same year locusts were observed in Hertfordshire and in eastern Scotland. Perhaps the immigrations of locusts and butterflies and moths are only a part of what may be a more general east to west migration of flying insects occurring in Europe in late summer.

Migrations in Phases Gregaria and Solitaria of Swarming Acrididae.

The arrival in the British Isles of *Locusta migratoria* ph. *solitaria* suggests that the solitary phase of this subspecies regularly migrates over long distances in the same general direction as ph. *gregaria*. In north-western India investigations carried out on *Schistocerca gregaria*, Forsk., during and since its last outbreak in 1926-1931, show that swarms of this species which breed during the winter and spring rains in the coastal and inland parts of Baluchistan migrate in late spring and early summer, with the prevalent south-west winds, into the Sind-Rajputana deserts, where the migration is terminated when the flights meet the summer monsoon rains. The generation produced in Sind-Rajputana returns with the north-east wind prevalent in late summer and autumn to the winter-rain areas of Baluchistan. Identical seasonal migrations have been conclusively shown to exist in ph. *solitaria* of this species (Ramchandra Rao, 1936 and 1937). Similar seasonal migrations between Baluchistan and Sind-Rajputana also occur in phases *transiens* and *solitaria* of *Locusta migratoria*, which has never been known to produce large swarms in India (Ramchandra Rao & Bhatia, 1939). In Tanganyika Territory swarms of *Nomadacris septemfasciata*, Serv., leave the Rukwa Valley for the Ufipa Highlands in the dry season and return to the valley with the commencement of the rains. In 1936 definite indications were obtained that such seasonal migrations take place also in ph. *solitaria* (Lea & Webb, 1936). Finally, an incursion of great numbers of *Schistocerca americana* (Drury), which is believed to be the solitary phase of the swarming *Schistocerca paranensis*, Burm., inhabiting Central and South America, occurred in the autumn of 1939 into the southern part of New Jersey State, U.S.A. (Fox, 1940).

Thus, long range migrations of phase *solitaria* occur in several, and perhaps in all, species of swarming Acrididae. It follows that in them the phenomenon of migration is not dependent on large numbers alone, but on some other factors, most probably those of seasonal meteorology, which have similar effects on all the phases. The ability to migrate is not restricted to phase *gregaria*, and it is definitely wrong to apply to it, as is often done, the name of " migratory phase."

Three main types of long-range migration can be differentiated in swarming Acrididae :—

(*a*) Long-range migrations of ph. *solitaria* which occur between and also in the outbreak periods, for even during these the locust population may remain in the solitary phase in parts of the outbreak area. This accounts for the arrival of ph. *solitaria* in the British Isles in 1898 and 1938. The individuals of the phase migrate in the same directions as the swarms and the range of their migrations may reach beyond that of the latter.

(*b*) Long-range migrations of swarms of ph. *gregaria*. During such migrations small swarmlets and separate individuals detached from large swarms may fly far beyond the area overrun by the latter, *e.g.*, arrival of separate individuals and swarmlets of *L. m. migratoria* in Sweden and the British Isles during the 1745–1754 and 1842–1850 outbreaks.

(*c*) Long-range migrations of small groups and separate individuals of ph. *gregaria* during local swarming in the outbreak centres when large swarms do not emigrate beyond the immediately adjoining areas, *e.g.*, small incursions of *L. m. migratoria* ph. *gregaria* into the British Isles in 1931, when swarms were confined to the Danube delta and Bessarabia. The occurrence of isolated ph. *gregaria* individuals of *L. m. migratorioides* in 1935 in the Borkou region of Chad Territory, where no swarms had been seen for some time (Zolotarevsky, 1936), was probably due to this type of migration.

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Summary.

1. From the study of the historical records of European invasions by *Locusta* from the 14th century to the present day, it is concluded that the subspecies concerned was *L. m. migratoria* originating in the West Pontian outbreak area. This area formerly comprised the lower courses of rivers draining into the Black Sea from the Danube to the Dniepr inclusive, and is now confined to the delta of the Danube. From here swarms migrated into central Europe and the eastern part of the north European plain. The northern part of the plain, the British Isles and Fenno-Scandia, lie on the outskirts of the invasion area, and as a rule were only reached by small detachments from swarms. The decline of the West Pontian outbreak centres was accompanied by the gradual decline of the area subject to invasions by large swarms, but during outbreaks small groups and separate individuals of ph. *gregaria* continue to reach the further limits of the invasion area.

2. The distances covered within a single generation by swarms of *L. m. migratoria* in temperate Europe (up to 1,600 miles) were comparable in extent to those traversed by *L. m. migratorioides* in tropical Africa.

3. Long-range migrations to the extreme limits of the invasion area are not confined to *L. m. migratoria* ph. *gregaria* but occur also in ph. *solitaria*. This is shown by the arrival of individuals of this phase in the British Isles during the period when the West Pontian outbreak areas are in a quiescent state. From this and from literature data on other locust species it is concluded that long-range migration is a regular seasonal phenomenon in swarming ACRIDIDAE, independent of the presence of large numbers or the phase.

4. The late summer immigration of *L. m. migratoria* into the British Isles may be a part of a more general east to west movement of flying insects which may occur in Europe at that season.

5. It is probable that *L. m. migratoria* sometimes oviposit in the British Isles, for they may arrive in a mature state, or during exceptionally hot summers in south-eastern England they may reach sexual maturity after arrival. The eggs, however, are apparently unable to survive winter conditions.

6. The western Mediterranean region, which is not subject to invasions from the West Pontian areas, is inhabited by a " race " of *Locusta*, intermediate in size between *L. m. migratoria* and *L. m. rossica*.

7. Endemic colonies of *L. m. rossica* and of " races " closely allied to it are scattered over central and northern Europe. They may be the relicts of the once continuous distribution area of *L. m. migratoria*, which probably spread into this area during the post-glacial boreal period, and then became restricted to favourable localities and underwent a reduction in size during the subsequent climatic changes.

8. There is no evidence that the British Isles are ever reached by migrants from the western Mediterranean regions or from endemic colonies in central and north-western Europe.

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THE PREVENTION OF OUTBREAKS OF THE PINE BEETLES UNDER WAR-TIME CONDITIONS.

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During the last twenty years, the Forestry Commission, several local authorities, and a large number of private woodland owners, have expended a total of several million pounds in an endeavour to replace the stocks of growing timber which were so heavily depleted during the last war. Several hundred thousand acres have been planted and a large proportion of these areas have been stocked with coniferous species.

The abnormal war-time fellings that are now being carried on will, in all probability, rapidly exhaust the remnants of mature crops and deplete the area of immature crops that now exist. It is, therefore, of vital national importance that the young plantations, which have been established at such great cost, should receive adequate protection in order that they may form a reserve growing stock which will, to some extent, help to replace the wastage.

Even under normal conditions, coniferous crops are particularly susceptible to damage by injurious insects, and, unlike annual crops, the damage that is caused is not confined to that year's growth. The damage done in any one year remains a permanent feature and may render valueless the results of a long period of growth. If a crop of 20 years' growth is ruined, it may be cleared and replanted, but the crop cannot be replaced in under 20 years.

During a period of excessive war-time felling, the necessity for vigilance and protection is of much greater importance than in normal times, because the facilities for the increase of the insects are enormously increased if proper control measures are not taken, It cannot be too strongly emphasized that it is useless to spend money on destroying adult insects after the damage has been done to the crops. It is absolutely essential that every effort should be concentrated on attention to the potential breeding-places in order to prevent the development of the insect populations.

Abnormal outbreaks of bark-beetles and weevils constitute the greatest menace. These outbreaks do not, as a rule, arise within the areas of young plantations where the damage will be done. They arise in felled areas and the insects migrate to the younger crops, consequently, even when a felled area is at a considerable distance from the nearest growing crop, it is necessary to prevent the area becoming a breeding-ground for insects, as they will travel several miles in order to invade the crops.

Concentration on control measures in certain areas and neglect to exercise control in other areas is futile ; it is necessary to control all potential breeding-grounds. In many cases the young crops which require protection and the areas which are being cleared are under different ownership ; in these circumstances the patriotic landowner, who does his duty to the State by expending large sums of money on the development of the country's timber resources, may be heavily penalised by thoughtlessness or neglect by others, who allow insects to breed and assume pest proportions on neighbouring estates. It is of the utmost importance that all those concerned with the felling and exploitation of standing timber should take every necessary precaution to see that the felling areas under their control do not become centres of infestation and a menace to their own growing crops, and to the property of their neighbours.

If the control of pine beetles is to be successfully carried out, it will be necessary for everyone interested in forestry and the exploitation of home-grown timber to co-operate in carrying out the necessary control measures.

Life-Cycle of the Common Pine-Shoot Beetle, Myelophilus piniperda, L.

The life-cycle of the common pine-shoot beetle normally extends over and is completed during one year. The winter is usually passed in the adult stage in hibernation. The date at which the beetles leave their winter quarters varies considerably. In the south of England, in a sheltered locality, on a sunny aspect, a prolonged spell of exceptionally bright, warm weather in February sometimes causes the adult beetles to emerge from hibernation and commence forming egg-galleries at the end of February ; but this work is not, as a rule, begun until towards the end of March. At high elevation in the north of England and Scotland, the formation of egg-galleries may be delayed until more than a month later ; but on sand dune areas near sea-level, even as far north as Moray Firth, in sunny situations, *M. piniperda* may commence making egg-galleries almost as early as in the south of England.

The period of development varies according to circumstances, but the normal period may be taken as three months from the commencement of the formation of the egg-gallery to the emergence of the first young beetle ; the young beetles normally begin to emerge about the middle of June in the south of England, later in the north in exposed places. Egg-laying is normally spread over a considerable period, as the eggs are laid during the progress of the construction of the egg-gallery ; consequently, the emergence of the young beetles from any particular brood may continue over a period varying from a few days to several weeks. On emergence from the breeding material, the young beetles are sexually immature and are quite incapable of producing a second generation. They proceed to feed in the growing shoots of pines and continue to do so throughout the summer. In the meantime, after completing the egg-galleries and laying the eggs that give rise to the first brood, the parent beetles may emerge from the egg-galleries and proceed to feed for a period in the shoots of growing pines. This is generally referred to as regeneration feeding and is for the purpose of recuperating the reproductive organs. After feeding in the shoots of growing pines, these parent beetles resume breeding operations in any suitable material that is available. They construct fresh egg-galleries and deposit another batch of eggs, which give rise to a second brood. The young beetles of the second brood usually emerge late in the summer, but in certain circumstances they may not emerge until the following spring. There are several variations in the life-cycle brought about by various combinations of factors, but these variations will not be described in this paper.

The life-cycle of the small pine-shoot beetle, *Myelophilus minor*, Htg., is somewhat similar to that described above. This species is present only in certain parts of Scotland. It generally commences to breed at least a month later than *M. piniperda*. The control measures will apply to both species.

Nature of the Damage caused by Pine Shoot Beetles.

The worst form of damage is that caused by young beetles feeding in the pith of the shoots of young trees during the summer. When attacking the shoots of young pines, the beetles definitely prefer the upper portion of the crown, where the shoots with the largest piths are found. Consequently dominant and sub-dominant trees suffer more severely than suppressed trees. In many cases the leading shoot is destroyed and sometimes also the whole of the terminal shoots of the uppermost whorls of branches. This destruction of the growing points causes various forms of malformation of the stem during subsequent development, and results in great reduction of the value of the crop, and a severe outbreak may actually cause its complete destruction.

In the case of older trees damage may be caused either by the beetles feeding in the shoots during the summer, or in the inner bark at the base of the trees during the milder periods throughout late autumn and winter. When the infestation is severe, a combination of these two forms of attack may result in the death of the trees.

Although in the majority of cases death does not take place during the year of attack, the vigour of the trees may be so reduced that they become suitable for the breeding purposes of *Myelophilus*, *Hylastes*, *Hylobius*, *Pissodes*, and other species, and the subsequent destruction of the tree is inevitable. Even when trees are not killed, large scale defoliation results in considerable loss of increment.

A certain amount of damage may also be caused by the beetles breeding in the bark of felled timber, if the broods are allowed to complete their development. This is due to the fact that their presence facilitates the development of blue stain fungus in the sapwood, which results in depreciation of the value of the timber. This is more particularly the case with *Myelophilus minor*, as the larvae of this species burrow into the timber to pupate if the bark is thin.

Other forms of damage of considerable importance occur, but these cannot be dealt with in this brief account. In the aggregate, the destruction caused by these insects is enormous, and they constitute one of the worst pests of coniferous forests.

Control Measures.

The prevention of destruction by pine beetles in growing stands very largely depends on the proper supervision of operations connected with the felling and conversion of the crops.

Efficient organisation, ensuring correct co-ordination between felling, extraction, and conversion, is all that is required to prevent felling areas becoming sources of infestation and a menace to surrounding pine areas. If this work is not efficiently organised and supervised, all efforts to control pine beetles in the growing crops will be rendered useless and futile.

Although felling areas provide exceptional facilities for the rapid increase of bark-beetles if the operations are carried out without regard for the rules of forest protection, there is no reason why the beetles should be allowed to increase. Any increase that takes place should be regarded as the result of negligence. The extent of operations, and consequently the amount of risk involved, is known in advance and the necessary steps can and should be taken.

Felling areas not only provide exceptional facilities for bark-beetle development, if control measures are neglected, they also provide unique opportunities for the reduction of the general level of the bark-beetle population and every effort should be made to utilise these opportunities to bring about the desired results.

Under normal conditions the treatment of felling areas should present little or no difficulty, especially where the areas to be dealt with are not exceptionally large. The extent of the areas to be felled is known beforehand and all the factors involved can be carefully assessed. On private estates, where game preserves are of considerable importance, it is necessary to avoid excessive activity in standing woods during the spring and early summer ; it is therefore desirable that felling and haulage operations should not be carried out during April, May, June and July. These are also the months during which pine timber should not be allowed to lie in or near the woods, on account of the risk incurred by pine beetles breeding in the bark. This leaves eight clear months during which all pine timber should be felled and cleared. If felling is commenced in August and the timber is extracted and entirely removed before the end of March, there is absolutely no risk of a pine beetle infestation. It is not necessary to bark any of the timber, and the woods are left undisturbed during the game breeding season. March is generally a dry month and affords a favourable opportunity for burning the lop and top. If the lop and top cannot be burned in March, it should be left until July and should then be burned. This will leave the ground clear for planting in the autumn and winter. The above remarks also apply to stands where large thinnings are being dealt with, except that in this case there will be no need to burn the lop and top. It should merely be cut into small pieces and left lying on the ground.

Under war-time conditions, where the yield of timber is very large and cannot be dealt with during the eight months, August to March inclusive, a certain amount of barking will be necessary but should be reduced to an absolute minimum, consistent with efficient forest management and the protection of growing crops. In this case felling should be commenced in August and completed before the end of the winter. Extraction of the timber should be begun as quickly as possible and every effort should be made to remove as much timber as possible before the end of April. Any timber that cannot be removed by this date should be barked in order to destroy the pine beetle broods. The barking of this timber should be completed before the end of May. Felling should not be resumed until the following August. In the meantime, the bark-beetles will have laid a second batch of eggs in the thicker parts of the lop and top ; this material should be burned in July in order to prevent the emergence of the second brood. If the above instructions are carried out there will be no risk of a bark-beetle infestation and the amount of timber that has to be barked in May will be relatively small.

If the timber is being converted on the spot or at a central sawmill for the area, and the abnormal conditions make it necessary for a regular supply of timber to be constantly supplied to the sawmill throughout the whole year, the procedure will necessarily be somewhat different. In this case, the successful control of the beetle population will depend almost entirely on the efficiency of the organisation and supervision of the operations. The most important point is to see that there is perfect co-ordination and a correct balance between felling, haulage, and conversion. It is absolutely useless to employ large gangs of men in felling enormous quantities of timber, which cannot be utilised within a reasonable length of time, and is merely left lying in the forest to breed insects and deteriorate. The number of men employed on felling, and the haulage arrangements should be regulated by the maximum capacity of the sawmill to deal with the timber. There is no point in felling more timber than is sufficient to maintain a six weeks stock constantly available for the sawmills. The probable requirements of the sawmill are known : if, say, 2,000 cubic feet of timber can be dealt with per week, the maximum amount necessary during any six weeks will be 12,000 cubic feet. Felling should be strictly regulated so that not more than 12,000 cubic feet of timber lies felled at any time during the operations. The exact figures will, of course, depend upon the capacity of the particular plant concerned. Extraction and haulage to the mill is always the chief difficulty and this should receive great attention. Felling should be so arranged that the timber can readily be removed in the order in which it has been felled, so that all felled timber will be dealt with in proper rotation and will be converted within six weeks of being felled.

If this arrangement is carried out there will be no necessity to bark any timber felled during the autumn and winter.

Myelophilus normally commences egg-laying towards the end of March in the south of England and at low elevation in sheltered positions. In order to prevent any risk of an increase in the bark-beetle population, it will be necessary to bark all timber roughly with a spade immediately before conversion at the sawmills, during April, May and June, and perhaps July. Examination of the incoming material during July will indicate how long it is necessary to continue barking the timber. This rough barking can easily be accomplished at an average cost of less than a halfpenny per cubic foot, as the timber is passed over skids between the dump and the saw bench. This estimate is based on actual barking costs. If the cost of this barking at the sawmills is spread over the whole of the year's operations, it will average out at about one-sixth of a penny per cubic foot, and no barking of timber will be necessary in the forests.

At high elevation in exposed positions in the north of England and Scotland, *Myelophilus* will not normally begin egg-laying until the middle of April. Barking timber at the sawmill will not be necessary until May in these localities; but it may be necessary to continue barking until the end of August, especially in districts where *Myelophilus minor* is present, as this species generally starts breeding much later than *M. piniperda.*

Although recent experiments have shown that spraying the bark of felled timber with insecticides on a large scale is impracticable on economic grounds and cannot be relied upon to give satisfactory results, the experiments indicate that spraying will be extremely useful for the treatment of slabs in sawmill yards. Therefore, if a quantity of slabs has accumulated at the sawmill in the spring as a result of operations carried out before the end of March, the heaps should be thoroughly sprayed with an insecticide to prevent pine beetles from laying eggs in them. This should be done before the end of March.

Where pitwood operations are being carried out, whether from thinnings or clear fellings, the work should be carried out on a six weeks' rotation, no material being allowed to remain unbarked after felling for more than six weeks during the months of April to July inclusive in the south, or May to August inclusive in the north. If the above instructions are carried out, there will be no risk of a bark-beetle infestation arising as a result of felling even under abnormal war-time conditions.

A full account of all control measures necessary for the protection of young plantations and standing woods will be found in a Bulletin, which is at present being prepared for publication.

Control of Pine Weevils.

It will be necessary to carry out further investigations before detailed control measures can be prescribed for dealing effectively with the pine weevil, *Hylobius abietis*, but in the meantime some check can be put upon the increase of these insects and the damage they cause by barking the stumps of pines while the larvae are developing before they pupate. The correct time for this operation can be ascertained by examination of the bark of one or two stumps at intervals. It is quite useless to bark the stumps before the larvae have begun to develop in the bast. This will normally be during the summer after felling in the south of England, if felling has taken place during the autumn and winter. In the north and in Scotland, at high elevations, the stumps may not become infested until the following year.

When the larvae are found burrowing between the bark and the timber, the whole of the bark should be levered off by means of a large barking iron, crowbar, or notching spade. This is quite easily accomplished, and the thicker the bark is the larger will be the pieces that can be levered off. In this way the stumps can easily be barked to a depth of several inches below ground-level.

THE CONTROL OF COCCIDAE ON COCONUTS IN SEYCHELLES.

By Desmond Vesey-Fitzgerald.

(Plates XI and XII.)

Introduction.

The present investigation was commenced at the beginning of 1936 and closed in June 1939. Originally it was supposed that two scale species, viz., *Ischnaspis longirostris* and *Pinnaspis buxi*, were to be brought under control. At an early stage in the work two other species had to be included, viz., *Chrysomphalus ficus* and *Eucalymnatus tessellatus*. Several other species of coconut-feeding Coccidae had also to be given passing consideration. All these species are unknown as pests on this crop in other countries. Apart from these coconut-feeding species a very large variety of other scales, one or more of which are of some economic importance on almost every plant grown on the islands, had also to be studied in order to obtain complete success. It will be evident therefore that the present problem soon assumed very diverse proportions which were fundamentally different from many other scale problems in which it is usual for one particular species to be investigated on one particular host. For these reasons, together with the fact that the better known coconut scale pests are unrepresented in Seychelles, it was necessary to attack the situation from an original angle. In the first place it was clear that general, as opposed to specialized, predators were desired, and also that all the different species of Coccidae present would have to be controlled simultaneously, for fear that the elimination of one might result in the increase of another. Secondly, because under humid tropical conditions seasonal variations in activity of the Coccidae is reduced to a minimum, detailed life-cycle studies, which form the basis of extra-tropical scale investigations, were replaced by a consideration of their ecological relationships. An explanation of these methods and the degree of control which has been obtained by their application forms the body of this paper. The control of the other scales on other crops will be recorded in a future publication.

Copra is the main export product of Seychelles. The area under this crop is said to be 28,230 acres. The yearly average amount of copra exported during the six year period 1931–1936 was approximately 4,630 tons. During the previous ten year period, 1925–1930, it was 5,045 tons.

The value of the 1936 crop, viz., 5,135 tons, was Rs. 865,000. This value allows an average return of about Rs. 31 an acre of coconut land. One acre of first-class coconut plantation will, however, yield a crop of 2,000 nuts, which has a value of Rs. 200. The low average figure emphasises therefore the extent of extremely poor areas, the poverty being dependent on various conditions, chief amongst which are soil deterioration and insect pests. For the purposes of pest control, therefore, the lower figure has most significance, and it is evident that control measures must be very cheap indeed if they are to be of any use in aiding the industry.

The present investigation has been financed by a free grant from the Colonial Development Fund amounting to Rs. 39,000. The work has been spread over a period of three years, the annual expenditure therefore has been Rs. 13,000, which is equivalent to a cost of less than 50 cents (*i.e.* 9d.) an acre, or about 1·5 per cent. of the total value of the crop.

Climate.

The rainfall is high, the mean annual average during the period 1916–1936 inclusive was 96·15 inches. The yearly precipitation is, however, very variable ;

during 1922, the driest year of the period, only 52·22 inches were recorded. During 1934, the wettest year, 145·06 inches of rain fell. In general, the rainfall is well distributed, the average number of days per year on which rain fell during the above period was 190. The wettest months are November–January during the period of the N.W. monsoon. From May to August, the period of the S.E. monsoon, the rainfall is very variable and is characterized by local heavy showers, which are, in the main, responsible for the annual and local variations in total rainfall. The intervening periods of calm at the beginning and end of the S.E. monsoon are usually rather dry.

The mean daily temperature remains very constant around 82°F. The relative humidity seldom falls below 70 per cent.

The Coconut Areas.

The plantations are situated on the coastal flats and the lower hill slopes, few plantations being successful as high as 1,000 feet. Coconut cultivations thus form a peripheral belt around the larger and higher islands, but some of the smaller islands are entirely covered with this crop.

The land is divided up into privately owned estates which, owing to the local laws of inheritance, ultimately become subdivided into very small parcels.

The size and number of holdings according to a census taken in 1932 are as follows :—

Under 10 acres	11–50 acres	51–100 acres	101–1,000 acres	Over 1,000 acres
1,213	237	57	78	7

The smaller properties are run by the owner or his family. The larger properties are worked by an owner or paid manager and a number of labourers.

The only regular work undertaken on the plantations is the collection of fallen nuts. In order to facilitate this all but the most neglected properties are cleaned each year. This work comprises the slashing of the more advanced stages of the weed succession.

Other work or cultivation is the exception rather than the rule. On coastal flats drainage and burying or burning of husks and leaves may be undertaken. On hillsides less cultivation is attempted. Except for occasional application of lime or seaweed and, near distilleries, mulching with cinnamon leaf refuse, manuring is not practised. No cover or green manure crops are in general use, although these have been advocated by the Department of Agriculture.

In addition to the removal of the crop the soil is further impoverished on some estates by the collection of leaves and husks for use as fuel in the distilleries. Run off of rain-water and erosion are serious on the hillsides, but it is seldom that steps are taken to stop this loss.

It is a common practice to cultivate ground provision crops, such as cassava and sweet potatoes under the coconuts. When the soil becomes too poor to yield a satisfactory return to this enterprise the land is abandoned to the ensuing weed growth. No attempt is made to revive the soil after these crops, and from the fact that garden cultivation is now most frequent at about 400 feet elevation it seems probable that the lower hillsides have already been worked out in the past.

It is most convenient to divide the area into edapho-topographic zones for the purpose of detailed study.

(1) *Coral Sand Flats at Sea-level.*

The coast line of the islands is made up of rocky headlands or hill slopes descending to the sea, which alternate with sandy bays or beaches. Inland from the latter there is usually a more or less extensive belt of flat land. The soil of these flats is composed of a bed of fine coral sand. A typical profile examined at Anse aux Pins, Mahé, may be described as follows :—Surface six inches stained or mottled a dark grey colour ; many fibrous roots in this horizon. Below this to a depth of one foot from the surface the sand is stained a lighter shade of grey ; roots of coconuts are frequent in this horizon. Below one foot to the water-table, which usually lies at about five feet below the surface, but varies somewhat seasonally, there is pure white coral sand.

This soil type is represented on all the so-called coastal " plateaux " of Mahé, Praslin and La Digue. The soil is extremely friable and water percolation is free. There is reason to suppose, however, that the water-table is somewhat stagnant, and drains designed to encourage water movement, though not necessarily water removal, are often beneficial on the lower-lying parts. A hard " pan " is often present at a few feet below the surface.

The weed-flora of these areas is characteristic. The most usual formation is an ankle-high mat of *Stenotaphrum complanatum*, but in more localised patches this gives place to a thick bed of the grass called locally " Herbe la seine." Frequently associated herbs are *Stachytarpheta jamaicensis*, *Isotoma* sp., *Turnera ulmifolia*, and rather more locally, *Lippia nodiflora*, *Desmodium* sp. and *Asystasia* sp. are also represented, but these plants are hardly typical of the area. Sedges are frequent and the little red-flowered parasitic plant *Striga hirsuta* is usually to be found. Cultivation, with the consequent loosening of the surface soil, especially in sunlit places, gives rise to a temporary mixed growth of annuals, usually dominated by the grass *Dactyloctenium aegyptiacum*. Any other of the above-mentioned plants may, however, form pure stands in these early stages of succession. It is evident, therefore, that the final formation is largely dependent on inter-specific competition, and represents a sort of equilibrium adapted both to the soil conditions and estate conditions. Certain of the plants, *i.e. Isotoma*, act as definite soil indicators, whilst others are typical of bad drainage, too much shade due to close planting of the coconuts, or neglect of weeding, etc.

It is evident that these coastal belts were the first to be planted with coconuts. The trees are therefore usually old and past their prime, which means they are probably more than 60 years of age. In general, especially on the plateau of La Digue, they are tall. Spacing is often irregular and the trees are definitely overcrowded. Elsewhere the trees are spaced at about 27 feet, and even at this distance robust trees are sufficiently close for their leaves to overlap with those of their neighbours, and the ground is shaded in consequence. At a later date, as a general rule, a second generation of trees has been planted and these have grown up under the shade of the older trees. The trunks of these younger trees have been drawn up towards the light, a fact which is made evident from the wide leaf-scars to be seen on the stem. Consequently the yielding capacity of these trees has suffered seriously. The horizontal and pendent leaves of the palms are usually clouded with " sooty mould " due to the presence of the Coccid, *Eucalymnatus tessellatus*, and many pinnae on the older leaves are bronzy-yellow or quite dry and brown owing to infection with *Pestalozzia palmarum*. It is probably true that the severity of the " sooty-mould " incidence is largely proportional to the density of the trees. The presence of *Pestalozzia* is a certain indication of poor drainage, and the yield is low. The average number of nuts per tree is 14. Barren trees are frequent and few trees carry more than 40 nuts. The monthly yield of a well managed 42 acres of plateau in Praslin is said to be 9,000 nuts. This is equivalent to an output of slightly over 2,500 nuts an acre, but this is most certainly above the standard of most plateau areas.

The plateaux may receive some cultivation. The important question of drainage is sometimes attended to, and an improvement in the appearance of trees adjacent to drains, or to natural tidal creeks, is always noticeable. The area is kept clean from the more advanced weed growth. Fallen leaves and husks are collected into heaps and burnt or else buried in trenches. A practice, which is reported to have trebled the crop on a certain property in Praslin, is to fill a " trash-hole " at the base of each tree with seven baskets of rotten sea-weed, to which is added half a kilo of guano and a similar quantity of ash.

The subsidiary crops grown on this area include *Casuarina*, these trees being allowed to grow up amongst the coconuts. *Casuarina* does very well on these plateaux, and its value as firewood in the local market often compares favourably with the returns obtained from coconuts. Patches of tobacco and tomato cultivation are also frequent.

(2) *Alluvial Soils.*

This section includes some of the richest soils on the islands, they are, however, restricted in extent and are rich at the expense of the hillsides. A considerable quantity of mountain silt has been washed right into the sea. For the purpose of study this section must be further subdivided.

(a) *Marsh areas.*—Between the coral sand plateaux and the lower slopes of the hills there is invariably a strip of low-lying, flat and usually flooded land. Many of these marshes are still abandoned and uncultivated, but the majority have been drained and planted up with coconuts. The soil of these areas consists of a bed of silt more or less mixed with coral sand. At a depth of one foot the soil is sticky and brown in colour, and with increasing depth changes into a very sticky dark brown or black mud with a boggy smell. The water-table is high and varies with tide and season. This soil frequently overlies a deposit of coral sand.

These marshes are the most recently planted areas in the colony. The trees are still young, not yet in their prime, some even have not yet reached bearing age. They are robust and vigorous but are usually too closely planted. Good crops are given by trees on these soils, the average per palm being about 30, and trees carrying over 50 nuts are quite usual. As elsewhere, the individual yields of the trees are variable but barren trees are rare, up to 74 nuts per tree have been noticed. The coconuts are planted on wide beds which alternate with drainage trenches. Patchouli is often cultivated under the coconuts, and for this purpose the land is heavily mulched with cinnamon leaves from the distilleries.

(b) *Talus-slope silt beds.*—Along the bottom, or actually forming the lower slopes of the hillsides, there is usually a belt of alluvial soil. These areas are situated behind the marshes described above, or, if the hills reach down to the sea, they may form a narrow coastal strip. The area appears more or less flat, though actually there is a slight fall towards the coast. The soil is composed of silt washed down from higher levels and often overlies sedentary soils. The profile is rather variable. At the surface is a layer of coarse silt which is reddish brown or even blackish in colour ; below this the soil becomes lighter in colour and stickier in consistency, and at a depth greater than one foot it contains much grey mud ; small or medium-sized stones are a feature.

These soils were amongst the earliest to be planted with coconuts. The trees are medium-aged or old, usually tall. Spacing is irregular and overcrowding is a common fault. The horizontal and pendent leaves are often clouded with " sooty mould," and many pinnae are dry. Scales are often bad. As a consequence of all these factors the average yield is often below 10 nuts per tree, but better samples average around 35 and in this case trees carrying over 60 nuts are to be found.

All kinds of subsidiary crops grow well on these soils, but both these and the main coconut crop usually suffer from competition with each other. Cash crops which do well on these soils are cinnamon, patchouli, ylang-ylang, etc. Food crops planted include cassava, sweet potato and bananas of all kinds. Timber trees do well in this area.

(c) *Quartz silt beds.*—A bed of pure quartz silt, reaching a depth of several feet in places, sometimes occurs in the mouths of drainage ravines. The surface layer of this deposit may contain much vegetable matter and be stained with humus. This soon becomes leached out from exposed areas, and a profile below this horizon presents a homogeneous section of coarse quartz grains of an opaque white colour. Similar beds of quartz silt occur at all elevations in suitable places, since the material is derived from the tops of ridges where bare rock is usually exposed. The surface of this rock is acted upon by weathering agents in such a way that the more easily soluble constituents are removed, leaving a " tapioca-like " mass of hard quartz grains loosely adhering to the surface. These grains finally become dislodged and are washed down to form these quartz silt beds. Coconuts growing on these soils are comparable with those on the talus-slope silt beds.

(d) *Mountain silt pockets.*—Throughout the hillside ravines pockets of silt occur. This material is derived from areas, immediately above, which have been eroded. The silt which collects resembles the talus deposit described under sub-section (b). The present soils occur, however, in restricted pockets or zones, collected on natural terraces or along the lower sides of ravines. In Praslin and Curieuse Islands, which have both been excessively eroded, soils of this nature are found all round the lower hill-sides and these beds are often the only places where coconut cultivation is successful on these two islands.

The coconuts growing in this soil are usually similar to, but rather better than, adjacent hillside coconuts growing in sedentary soils. Blight from the *Pinnaspis* scale, which will be discussed elsewhere, may become serious in these situations.

Subsidiary crops cultivated on this type of soil will also be discussed under the heading of sedentary types.

(3) *Sedentary Soils on the Hill-sides.*

By far the greatest area of coconut plantations stand on this type of soil. It extends from sea-level to over 1,500 feet, although unbroken coconut cultivation is not found much above 500 feet. This soil may be deep or eroded, cultivated or worn out, naturally terraced by rocks or quite unprotected from wash. Past treatment, vegetation, inclination, topography, elevation and aspect are all variable factors affecting the mechanical condition and fertility of these soils. It is difficult therefore to generalise but it is hoped that, if the more normal variations surrounding an average set of conditions are discussed, some general principles will be emphasized.

A soil on a medium coastal slope at 150 feet elevation in North Mahé may be examined as a type. The profile may be described as follows :—Surface four inches a friable light brown coloured granitic loam, which between four inches and one foot becomes lighter coloured. Below one foot the consistency is more tacky, the texture remains the same same and the colour is yellower. At two feet the soil is a red clay enclosing many fine quartz grains, and at three feet disintegrating rock is embedded in the clay-like matrix. This " raw " kind of subsoil may have a depth of very many feet. When the primary forest was cleared the rich superficial humus soil was soon destroyed and the heavier mineral base was all that remained. So long as this was kept covered with vegetation serious soil wash was avoided, but under the hand of the cultivator erosion commenced. The extent of this erosion depends on the inclination of the slope, the nature of the terrain and, other factors being equal, the elevation and aspect. The hill-sides are deeply cut into drainage ravines alternating with ridges, the slope being gentle or steep. Unweathered granitic boulders are very numerous and these have an important mechanical function. The slope may be steep and boulders scarce. In this case erosion is likely to be serious if the vegetation is removed. Elsewhere the boulders may be numerous and break the slope up into natural terraces, or confine the soil into pockets, and consequently soil wash will be reduced.

Erosion along the crests of ridges is usually severe, and from these all the more friable soil has been washed away. In this case the raw subsoil lies at or near the surface. This kind of country is known locally as " tuffe." In very extreme cases, as for instance over parts of Praslin and Curieuse Islands, even this tuffe may have been deeply scored into gullies. The eroded soil in these circumstances tends to collect as a talus deposit round the foot of the slope on top of the sedentary soil.

This mechanical removal of the top soil causes the area to become unsuitable for cultivation and eventually barren of all vegetation. The soil also loses its natural fertility through continual cropping if no replenishment of plant food takes place. Under coconuts a fair crop can be maintained for many years, even though nothing goes back to the land except the fallen leaves and dry husk. But in many localities annual crops have been grown under the coconuts until the soil has become quite exhausted, which has been much to the detriment of the coconuts, and in extreme cases they have not been able to survive.

The quality of the soil can often be judged by a survey of the weed flora. On hill-sides, where the soil is typical and is conserved in boulder-pockets, an ankle high herb mat covers the ground. The characteristic species represented are *Desmodium* sp., *Asystasia* sp., *Stachytarpheta indica*, *Mimosa pudica*, and various grasses. If this growth is not slashed coarse herbs and shrubs become dominant. If the soil is somewhat worn out, owing to long cropping or to having been planted with cassava, a coarse growth of waist-high herbs takes possession of the land. *Stachytarpheta indica* dominates, and usual associated plants are *Turnera ulmifolia*, *Pennisetum purpureum*, a plant locally known as " herbe tabac," and, especially at higher levels, the grass *Paspalum plicatulum*.

In many parts of Mahé this formation is superseded by a close mat of the grass *Panicum parvifolium*. On very eroded dry soils a rather open knee-high growth of *Heteropogon contortus* is characteristic. Tuffe is largely bare of herb vegetation, but various native shrubs may exist.

Soils which are rather better than average, owing to the many supporting boulders, absence of over-cropping or other causes, are indicated by a six-foot growth of giant herbs such as *Lantana* sp. and *Panicum maximum*. Soils which may be considered in really " good heart," such as those which have until comparatively recent years supported forest growth and vanilla cultivation but on which young coconut plantations are now established, are characterized by a further set of " indicator " herbs, viz., *Nephrolepis* fern, *Commelina* sp., and the grass *Chaetochloa* sp.

Although coconuts have been long established on the hill-sides below about 500 feet it seems that these areas were planted after the plateaux and foot-hill alluviums. Owing to the various factors and vicissitudes of the environment, the present-day plantations present a very varied appearance.

The spacing of the trees is usually irregular and dependent on the relative positions of boulders and pockets of soil, but the palms are rarely crowded. Trees of the same age are apt to vary greatly in height and robustness according to the qualities of their immediate environment. Tall trees are exceptional, the average height does not exceed 25–30 feet. In general, poor trees are located on ridges and the tops of banks and robust trees in ravines and along the bottom of banks. " Sooty-mould " incidence on the leaves is less severe than is the case on plateau trees. Where the *Ischnaspis* scale is prevalent the older leaves are a homogeneous olive-green colour. On dry hill-sides the pinnae are often peppered with little rectangular brown spots, and on ridges the leaves tend to be yellow. Trees exhibiting leaf-spotting and yellowing are rarely severely attacked by scales. The yield is low, the average crop of a 100 tree sample from twenty localities was 13 nuts per tree. The actual number of nuts per tree varied between nil and 50, barren trees being very numerous.

The weed growth on hill-sides is usually slashed in order to facilitate the collection of nuts, but owing to the danger of soil wash too close weeding is not desirable. Contour trenches may be dug behind trees into which trash is thrown, this practice being beneficial since it checks the run-off of rain-water. Where the soil is shallow and eroded, trees benefit by having earth, held in place by a retaining stone wall, piled around the bole.

The most usual subsidiary crop is cinnamon. This shrub forms an under-story growth which is prevented from crowding the coconuts by the periodical cropping of the leaves for distillation. At higher levels, shifting provision gardens, in which cassava and sweet potatoes are grown, are frequent. This enterprise cannot be recommended, since the land is rapidly exhausted to the detriment of the standing crop and pest incidence is often high on the site of old gardens.

1. Ischnaspis longirostris, Sign.

Laing (in correspondence) writes on this synonymy as follows :—" Signoret's type of *longirostris* is not, so far as we know, in existence, but by consent it has been defined as the same as what Douglas called *filiformis*, a species about which we can speak since authentic material named by Douglas is still in existence. Since *longirostris* was described in 1882 it takes precedence over *filiformis* described in 1887. The species in Seychelles is what Douglas called *filiformis*, and that has by consent become known as *longirostris*."

Ischnaspis is a small genus, and the other species included in it are not very close to *longirostris* and are not recorded from Seychelles. It is therefore easy to recognise this scale by superficial characters. The external appearance of the adult female is a shining black, usually rather curved, shield which is between eight and ten times as long as it is broad. At the forward end is the persistent dead skin of the first-stage nymph, which is pale yellowish with two dorso-central darker areas. On some hosts, *e.g.*, *Raphia* palm, the shield is covered with a mealy bloom. The female insect, which shelters under this shield, is bright yellow and between four and five times as long as it is wide. The shield is therefore longer than the insect it covers and so there is an unoccupied space behind the body of the female. This space represents the " brood chamber," from which the nymphs escape by pushing their way under a flap at the extreme end of the shield. The male has never been seen.

The " black thread scale " has been recorded on coconuts from the West Indies, West Africa and Ceylon. In none of these countries however is its incidence at all severe. The species is not included in any other lists of coconut scales which have been seen. In Seychelles *Ischnaspis* is the commonest scale on coconuts, the incidence in certain cases being very severe. *Ischnaspis* is evidently a comparatively recent introduction into the islands, and though its immediate source is unknown the progress of its spread can be traced through the literature. Green (1907) in an account of the COCCIDAE of Seychelles does not mention *Ischnaspis*, but subsequently (1916) records it from oil palm. About 1925 it is evident from the annual reports of the Seychelles Department of Agriculture that the spread of *Ischnaspis* on coconuts was being looked upon with concern. After 1928 references to the harm caused by this and other scale species become very frequent, and three years later Stockdale (1931) recommended that a special investigation be inaugurated.

Life-history.—The eggs are comparatively large, they are a deep orange colour, oval in shape and have a shiny texture. Oviposition is slow and progressive, that is to say, the brood of one female at any one time is represented by several stages.

There may, for instance, be 4–5 developing eggs within the body of the female, one or two newly laid eggs in the brood chamber, two or three newly hatched but quiescent nymphs resting in the brood chamber together with a mass of white empty " egg-shells " belonging to previously hatched nymphs which have already left. Individually *Ischnaspis* appears to be not very prolific and the progeny of one female seems to be limited to between twenty and thirty offspring. The eggs occupy the greater part of the abdomen of the female. Their length about equals the width of the female's body within which they lie at an angle to its long axis. The egg furthest within the abdomen is of a rather indefinite shape and the content is granular in appearance. The egg nearest to the tip of the abdomen on the other hand contains a fully formed embryo, in which all the parts of the future nymph can be seen. The stylets are directed forwards, each one terminating in a coil, one on either side of the head region. The six legs are directed backwards and pressed against the abdomen. In this stage the egg leaves the body of the female and comes to rest in the brood chamber. Very soon after laying the chorion bursts and the nymph is liberated. The antennae now become free, and the stylets move backwards and become more loosely coiled. The legs, however, remain pressed along the abdomen and the nymph lies motionless for a time. Gradually the legs gather strength and turn until they occupy their normal position. The nymph is now ready to push its way out from the brood chamber. The migrating nymph is yellow. Experiments indicate that the active phase does not last much longer than 24 hours, and during this time the nymph normally finds a place to rest and forthwith inserts the stylets. The first moult takes place in about three days. The complete first-stage nymphal skin, including the prominent antennae, is cast off but is retained as a cover under which the second stage nymph shelters. The second stage nymph resembles the adult in being devoid of legs and antennae, its body being, however, relatively less elongated. The black shield now begins to appear from under the posterior edge of the persistent first stage skin and further development is limited to the gradual elongation of this shield and maturation of the female insect underneath. Development proceeds throughout the year.

Ecology.—*Ischnaspis* is found on all the granitic islands except the smaller and more distant ones ; the species does not occur on the madreporic islands. As a pest it is most severe in Mahé, Silhouette, La Digue and Felicité. Only local damage is caused by this species in Praslin.

Ischnaspis may be found on a wide range of host-plants, in fact if the presence of one or two adults be taken as the criterion it seems that the host list would be unlimited. Certain plants are, however, more favoured and a list of economic species other than coconuts, which are seriously attacked by the species in Seychelles, includes the following :—*Anona reticulata* and *Cherimolia,* banana (all vars.), cinnamon, coffee (*C. robusta*), litchis, mango, oil palm, *Raphia* and *Zizyphus jujuba.* The incidence of the species on palms is of special interest. Coconut, *Raphia* and oil palm are favourite hosts, and in East Africa the oil palm is attacked even in places where *Ischnaspis* is so rare that it is not found on any other plant. In Seychelles exotic palms growing in the Botanical Gardens are heavily infested, but endemic palms are rarely if ever attacked. *Ischnaspis* attacks all the varieties of coconuts which are grown in the islands, viz., " Seychelles," " Ceylon " and " Dwarf." Poor, stunted trees growing on eroded ridges are seldom attacked by this or any of the other species of scales, but a more interesting discrimination is the tendency for *Ischnaspis* to avoid trees growing on coral sand. In Mahé, where plantations on coral sand are small in proportion to those on alluvial and sedentary soils, the incidence of *Ischnaspis* shows little diminution on the former ; but in Praslin a marked reduction may be noticed as is illustrated by the following sample count on two adjacent areas :—

Locality	Percentage of infested leaves/trees*							
	Coral sand				Alluvium or sedentary			
	3	2	1	+	3	2	1	+
Anse Kerlan	—	—	—	—	8·5	7·7	32·5	31
Grande Anse	—	—	13·5	11·1	—	2·3	53·8	32·2

*See note on degrees of density below.

The absence of *Ischnaspis* on the madreporic islands is significant in this connection, since it is certain that opportunities for the arrival of the scale on these islands have not been lacking.

The scales settle on the lower surface of the pinnae, rarely extending to the upper surface. The individuals are scattered more or less evenly over the surface, there being no sign of localised clustering or selection of special areas ; pinnae, petiole and fruit are all attacked. As was indicated above, the individual scales settle down quite independently of each other ; their shields grow and after the insect dies the dry shields remain on the leaves. The older the leaf the longer it is exposed to attack and the denser the scales become. In later stages clear spaces become rare and the nymphs are forced to sandwich themselves between the others, so that their shields often become bent or distorted from the pressure exerted by the living or dead bodies of their neighbours.

In order to assess the degree of attack from which any particular tree or leaf is suffering arbitrary degrees of density have been employed. Four degrees of density can be defined, *viz.*, " Mark + "=scales present in very small numbers with large and irregular spaces of one square inch or more between the individuals ; scales at this density cause no damage to their host-plant. " Mark 1 "=scales rather evenly peppered over the surface, but neighbouring individuals not in contact with each other ; this density gives about 100–150 adult scales per square inch. " Mark 2 "= scales more thickly sprinkled on surface, about half the number in contact with their neighbours ; at this density there are, on an average, about 300 adult scales per square inch. " Mark 3 "=scales densely clustered on the leaf-surface, each one in contact with one or more of its neighbours ; at this density anything from 700–1,000 adult scales are packed on one square inch of leaf-surface. A very heavily infested leaf with no vacant spaces at all was found to be supporting 1,162 adult scales to the square inch, and besides this there were many hundreds of first stage nymphs present. The total number of scales present upon a leaf is actually the accumulation of several generations, since the dead shields do not drop off. The percentage of living insects present is often inversely proportional to the density. Thus only very few of the scales forming a heavy " Mark 3 " density may be living, but in a lighter " Mark 3," giving some 700 to the square inch, up to 75 per cent. may be living. A " Mark 2 " may have between 75 to 100 per cent. living, and in " Marks 1 and + " all the scales are usually living. Upon an infested coconut tree the scale density increases with the age of the leaf. Upon an average tree bearing 23 leaves, the seven oldest will support a " Mark 3," the next six a " Mark 2," the next four a " Mark 1 " population ; thence to the heart leaves with only scattered scales at " Mark +," the youngest leaves of all probably being quite clean. Although the severity of attack may not be quite commensurate with the density owing to the diminishing percentage of living scales, it is certainly the older leaves which are most damaged. *Ischnaspis* does not " burn " the leaves but causes a characteristic yellow and brown mottling which can be clearly seen on the upper surface of the pinnae. At a distance the infested leaves have an unhealthy olive-green colour. Any leaf supporting a scale density greater than " Mark 1 " exhibits these symptoms. The infested tree suffers a loss in vigour as a consequence and the crop of nuts is reduced. Besides this damage there is some evidence that green nuts which become badly covered with scales fail to develop properly.

In Seychelles there were no natural controlling factors of *Ischnaspis*. A lighter incidence on certain soil types has been mentioned above, but this is only a general tendency, since in badly infested areas the scales spread on to trees no matter what the soil type. The relative immobility of the nymphs seems to be the only reason why very young leaves remain free from heavy infestation, and on old leaves scale development is only limited by lack of space. Interspecific competition between coconut-feeding species must be severe. The only trees relatively free from *Ischnaspis* attack are those upon which either *Pinnaspis* or *Chrysomphalus* find conditions especially favourable and are able to crowd out *Ischnaspis*. No parasite or predator, except a quite ineffective undetermined mite, is known from Seychelles. A few scales in certain humid situations become attacked by the entomogenous fungi *Pseudomicrocera henningsii* and *Myriangium duriaei*. Fungus-infected *Ischnaspis* have been found on coconut, coffee and oil palm, but the pest is in no way reduced even temporarily or locally by these agents. A mortality of immature scales is rather frequent. No satisfactory explanation of this fact has been ascertained, but since it is most in evidence on severely infested leaves, it is possibly due to some change in composition, which also brings about the yellow and brown mottling. In Tanganyika Territory *Ischnaspis longirostris* is parasitised by the Aphelinid, *Aphytis chrysomphali*, Mercet. Parasitised specimens were collected from oil palm at Amani, and scales bearing parasite emergence-holes were seen in the collection of the Department of Agriculture at Morogoro on coffee leaves from Bukoba.

2. **Pinnaspis buxi, Bouché.**

This species has been recorded from U.S.A., West Indies, Panama and Europe, on *Buxus*, *Dictyosperma*, *Areca*, *Pandanus*, *Anthurium*, *Thrinax*, *Dracaena* and coconut (MacGillivray, 1921). There are several rather closely allied species in the genus, several of which occur in Seychelles, where *P. minor* is also recorded on coconuts (Dupont, 1932).

The present species appears to be rare as a coconut pest in other countries, since its name does not appear on any pest lists of this crop which have been seen. In Seychelles, though very locally distributed, it is a serious pest which does more harm to individual coconut palms than any of the other species of scale. Like *Ischnaspis*, *Pinnaspis* is a comparatively recent arrival in the Colony. Green (1907) does not mention this species. Dupont (1918) gives a complete list of insects attacking coconuts in Seychelles but does not include *Pinnaspis*, but by 1925 the same writer records *Pinnaspis buxi* as the most troublesome scale on coconuts (Dupont, 1926).

Life-history.—The first-stage active nymphs settle on the feeding surface and soon become immobile. The second stage nymphs shelter under the persistent oval skin of the first-stage nymphs. The " shield " emerges from under the posterior half of this dry skin in the form of a flat, hand-shaped, slightly corrugated flap. At first the length of this flap approximates to its width. When full-grown, however, the length exceeds twice the width. The texture of this shield is papery, brown in colour and semi-transparent. The body of the female insect is not so large as the surface covered by the " shield " and lies just behind the persistent nymphal skin. Behind again is a wide vacant space which forms the " brood chamber." A female is ready to oviposit one month after it comes to rest on the leaf. All the eggs, which are limited to less than thirty, are laid over a short period and they are sheltered in the " brood chamber " arranged in two, more or less parallel, rows. When first laid the contents of the eggs are granular, so some days must elapse before the nymph is ready to emerge. The unhatched eggs are yellow in colour but after they have hatched the dry chorion is white. Living adult female scales are therefore a sleek brown colour, whereas the dead scales from which all the brood has hatched appear dry and whitish. Development proceeds throughout the year. The male is unknown.

Ecology.—Pinnaspis occurs on the larger granitic islands and is responsible for serious damage in Mahé, La Digue and Felicité. A bad outbreak also occurred in recent years on Coetivy, which is a madreporic island. Species of *Pinnaspis* occur on various host-plants, but amongst the palms the only species seriously attacked besides all varieties of coconut is the Areca palm. The species rarely attacks coconuts growing on beds of coral sand, nor is it found upon trees growing on poor eroded lateritic soils. The trees growing on the richer alluviums along the foot of the mountains are frequently attacked, but here the *Pinnaspis* is unable to compete for space with *Ischnaspis*, and it is rare that the former is the dominant scale on the tree. In the mountains at a mean elevation of 400 feet, *Pinnaspis* is frequently a serious pest and the infested trees form a yellow band across the hill-sides which can be clearly seen when the islands are viewed from the sea. The trees at this elevation were planted later than those lower down and so they are at present young or medium-aged palms in full bearing. Until erosion has removed the surface loam such sites are cultivated by small-holders or by labourers working on the property, and provision crops, chiefly cassava and sweet potato, are grown. After the crop has been removed from the land a rank growth of coarse herbs and shrubs covers the area, and if cleaning or further cultivation is not practised a small wood of such trees as *Albizzia lebbek* and *Adenanthera pavonina* may grow up. It is in such places that the most severe outbreaks of *Pinnaspis buxi* occur. COCCIDAE of various kinds, besides the coconut species, are often numerous in such localities. *Lecanium nigrum* is common on the cassava. *Pseudococcus* sp. and *Icerya seychellarum* occur on a variety of hosts, especially the *Albizzia* and *Adenanthera*, and various species of *Lecanium* cover other trees, notably *Ficus* sp. A direct result of this concentration of COCCIDAE is a great influx of the ant, *Technomyrmex albipes*, a species which further benefits by the rank vegetation which provides abundant shelter for its nests. The ants derive their nourishment from these Coccids, and their great abundance entirely prevents the imported COCCINELLIDAE from approaching these scale infestations. In such circumstances, therefore, the predators become helpless, and the coconut trees suffer very severe scale blighting, which is usually very closely restricted to the area where the above conditions prevail. Year to year records, which are presented in a later section, indicate that the imported predators are efficient at reducing these severe outbreaks so long as they are given a chance, but when the ants are swarming on every plant their success is problematical. In order to turn the balance in favour of the Coccinellids the ants must be reduced, and this should be attempted by attacking both their food supply and their sheltering places. All heavily scale-infested and sooty-mould-covered trees which have grown up in the area should be destroyed. Cassava planting, in view of the fact that this crop harbours *Lecanium nigrum*, should be stopped. The area should be clean-weeded, and all dead leaves and rubbish lying on the ground, in which the ants find shelter, should be burnt.

A factor which appears to have caused a slight increase in the intensity of recent outbreaks of *Pinnaspis* is certainly the reduction of *Ischnaspis*. In the presence of *Ischnaspis* the pinnae of the leaves never become dry and rolled, however severe the attack may be, but in the presence of *Pinnaspis* all the pinnae eventually become dry and rolled. Each of these rolled pinnae provides the ants with shelter on the spot. Hence if a tree is attacked by both *Ischnaspis* and *Pinnaspis* a proportion of the pinnae remain unrolled and suitable for the feeding requirements of the Coccinellids and at the same time unsuitable for sheltering ants. In this case the balance remains in favour of the predators. A great reduction in *Ischnaspis*, besides providing more space for *Pinnaspis*, also causes a higher percentage of scale-infested pinnae to be rolled. These circumstances are detrimental to the predators but favourable to the ants. This ant threatened to be a serious handicap in the early stages of the control work, but later developments have shown that it is only under the above-mentioned circumstances that it is a serious menace, and this menace can be alleviated along the lines indicated above. The question of the relationship of the ant, *Technomyrmex*, with Coccids will be considered in another paper.

The nymphs of *Pinnaspis* settle on the lower surface of the pinnae, rarely extending to the upper surface. They tend to settle in clusters around an older scale. The " ensemble " on a leaf is therefore composed of numerous little groups, and in the early stages of attack these groups tend to be arranged in rows along the leaf veins. As the population becomes denser the spaces between the groups fill up, until the whole of the available surface is covered. For practical purposes the incidence of *Pinnaspis* can be assessed in a way similar to that employed for *Ischnaspis*, except that, in the case of *Pinnaspis*, groups rather than individual scales were used as the unit. Thus at " Mark 3 " density no bare leaf surface is left exposed. In a " Mark 2 " density some uncovered spaces are still present. In a " Mark 1 " density the groups are more or less separate from each other and appear to be arranged in parallel lines. A " Mark + " density is one in which the groups are only scattered over the leaf and one or more complete square inches of leaf surface are left without any scales being present.

The attack of *Pinnaspis* is acute, that is to say, at any one time all the scales on a leaf may be living, but if the leaf be examined at a later date they will all be found to be dead, the young scales having migrated elsewhere. This fact explains the reason why the attack of *Pinnaspis* is so severe while it lasts and also why palms in certain localities may be suddenly blighted whilst elsewhere they gradually recover from an attack.

In the early stages of attack the scales cause faint yellow mottlings which may be best seen on the upper surface of the pinnae. Later these markings become more distinct and take the form of yellow and brown spots, which finally become so numerous that the whole leaf appears yellow. Subsequently the pinnae die from the tip inwards. All except the youngest leaves on a tree may be " burnt " and as a consequence the crop is reduced to nil. Rarely a tree may be killed, but more frequently it is not permanently injured, and after the scale attack passes off the " burnt " leaves are gradually replaced and the crop goes up again.

Pinnaspis is parasitised in Seychelles by a Chalcid which has not yet been determined. A few scales have been found infected by a fungus, but it is not certain if this is parasitic or if it grows only on dead scales. These agents are, however, of no use in limiting the *Pinnaspis* population. There is reason to suppose that competition for space is fairly severe between *Pinnaspis* and *Ischnaspis*, and a reduction in one may lead to an increase in the other. A certain amount of benefit is claimed by some planters from the practice of cutting and burning infested leaves. It seems quite possible that small outbreaks may be arrested in this way, but in cases of advanced attack so many leaves would have to be cut off the tree in order to rid it from scales that serious injury to the palm might result.

3. Chrysomphalus ficus, Ashm.

The female insect may be recognised in the field by the characters of its shield, which is circular. Rather to one side of the centre is a raised boss which is of a reddish brown colour, the rest of the shield being an umber brown. There is a semi-transparent marginal flange all round the perimeter of the shield. The body of the insect is bright yellow and does not completely fill the space under the shield. The male, which is rather more abundant in individuals than the female, is covered by a similar shield, which is, however, smaller and oval in shape owing to an extension of the marginal flange at one point on the perimeter.

Life-history.—The life-history of *C. ficus* has been studied in Egypt by Priesner (1931), and in Palestine by Schweig & Grunberg (1936), in both cases on *Citrus*. These authors studied the insect outside the tropics and, therefore, season and temperature made a great difference in the rate of development. In Seychelles breeding continues throughout the year without any interruption.

Ecology.—*Chrysomphalus ficus* is found on all the granitic islands and probably on all the madreporic islands as well. As a pest it is most severe on the larger granitic islands. This species occurs on a wide variety of host-plants in Seychelles, including amongst economic plants all varieties of coconut, cinnamon, and *Citrus*.

As a serious pest on coconut this species is very local in distribution. The most severe incidence usually occurs where the trees are growing in pockets of comparatively rich soil at low elevations. An examination of outbreaks almost always suggests a recent enrichment of the soil as a predisposing cause. On hill-sides at Point Connan a severe outbreak could be attributed to a recent application of " night soil." At Glacis, where a similar outbreak occurred, the trees were growing in pockets of soil held by boulders and in these pockets leaves and other refuse had collected. On St. Anne island bad outbreaks in a ravine could be attributed to huge accumulations of husks which were piled up there. At Anse Boileau a scale patch was evidently due to cattle being continually tied under the trees. At Anse Baleine, and elsewhere in Mahé and Praslin, trees in the neighbourhood of cinnamon-leaf refuse dumps often suffer a severe attack. On coconut, the scales settle on the lower surface of the pinnae, where they are usually concentrated towards the base, but in bad outbreaks they spread to the upper surface. They also occur on the green nuts. This species has been recorded from the majority of the trees examined, but usually it is represented only as scattered individuals amongst the more abundant species of scales. When the attack starts to become severe the individuals collect in small clusters localised on certain parts of certain pinnae. Such clusters may be found on any aged leaf, even including quite young leaves which may be actually more or less free from *Ischnaspis*. When the attack increases, larger areas of more numerous pinnae are covered, and in local serious outbreaks *Chrysomphalus* becomes the dominant scale on the tree and all the pinnae of the older leaves show a high incidence. Owing to this localised clustering of the scales the incidence assessment has to be based on a different principle from that employed for *Ischnaspis* and *Pinnaspis*. In the case of *Chrysomphalus* scattered scales occurring amongst the other species represent " Mark +." If there are one or more definite clusters of *Chrysomphalus* present this is assessed as " Mark 1." If the cluster has extended to form a patch covered with the scales which occupies a considerable proportion of the pinnae, this is assessed as " Mark 2." If the lower surface of the pinnae is covered by the present species, which is then the dominant scale, this represents a " Mark 3 " density. *Chrysomphalus*, besides being local in distribution, is also very restricted in its occurrence on the palm. It is very seldom that a whole leaf is covered with the scales. A " Mark + " incidence may be fairly constant on all the pinnae of most of the older leaves, but any of the higher densities are much more restricted. A certain pinna may be covered with a " Mark 3 " density and the one next to it may be quite free from this species. Only in a few localities is the attack severe over the whole tree, and in these circumstances considerable damage results. Even one individual scale will cause a fine yellow line to mark the leaf at the point where it is feeding. A cluster of these scales causes a bright yellow patch, which increases with the size of the group of scales present. A patch of this nature eventually dies and that part of the leaf turns brown and becomes dry. A " Mark 3 " incidence will therefore cause the whole pinna to become dry and rolled and if the majority of the pinnae are attacked the leaf will be killed. In these circumstances the damage caused is severe and the crop is reduced.

Chrysomphalus ficus is parasitised in Seychelles, both the male and the female scales having been observed with parasite emergence-holes. Parasitised scales have been collected from the granitic islands, viz.: Mahé, Praslin and Felicité, and from the madreporic islands, viz.: Farquhar, Desroches and Darros. The parasite which has been reared from material collected in Mahé is *Aspidiotiphagus* sp. This Chalcid pupates within the empty skin of the scale. The emergence-hole through the shield is round and is situated to one side of the boss. The excrement of the parasite is deposited in two parallel rows along the inside edge of the empty skin of the host.

4. Eucalymnatus tessellatus, Sign.

The adult female is a dark red-brown in colour; the body is flat, slightly raised in the mid-dorsal region; the shape is oval, 3 mm. × 2 mm. in size. The male is unknown. The nymphs are either born alive or hatch out immediately after oviposition. Each female gives birth to probably less than two dozen young. The nymphs at first shelter under the parent scale in the " brood pouch " which consists of an impression in the ventral surface of the body immediately behind the metathoracic pair of legs. The first stage nymphs are flat, oval, rather more rounded at the front end, and with a cleft at the anal end, which encloses a short median process and is flanked by two strong bristles; the colour is purple-brown; legs strong; antennae large, surmounted by two strong bristles. The medium-aged nymph is only periodically active, and the body is very flat with a wide flange round its perimeter, which hides nearly the whole length of the legs and half the length of the antennae. The colour of this stage is green.

Ecology.—Eucalymnatus tessellatus is found on all the granitic and madreporic islands, but although this species has been recorded from every sample count which has been taken, it is not normally in itself a serious pest. This, or a very closely allied species, is found on a wide variety of plants. Those of economic importance which are most affected in Seychelles include:—coconut, especially orange dwarf varieties, cinnamon, mango, *Eucalyptus citriodora*, papaw and some timber trees such as " takamaka " (*Calophyllum inophyllum*).

This scale is scarce on palms growing on poor and eroded soils in the mountains, but trees growing in alluvial soil or coral sand are sometimes severely attacked. In the case of alluvial soils it is noticeable that the better the soil and the more robust the trees the higher is the incidence of *Eucalymnatus*. The most serious damage occurs on trees growing on coral sands, especially those which are badly drained. On the badly drained plateaux at Côte d'Or and Grand Anse in Praslin island, *Eucalymnatus* is the dominant scale. The trees in these circumstances are often of a poor and ragged appearance; the older leaves are of a bronzy yellow colour with many of their pinnae dry, and the crop is low. These symptoms are not, however, due to the attack of *Eucalymnatus* but rather to the limitations of the environment, such as bad drainage or a subterranean hard pan. These circumstances must, therefore, be regarded as those which predispose a tree to attack by this scale.

The scales settle on the lower surface of the leaves, rarely on the upper surface or on the green nuts. They are usually found rather towards the tips of the pinnae, especially of those that are situated towards the apex of the leaf. This scale comes to rest on quite young leaves. Usually the only leaves which are entirely free from attack are those that are just emerging from the heart. The old scales slip off the leaf when they are dead. Hence the greatest density of scales is found on the medium-aged, horizontal leaves. *Eucalymnatus* is a much larger species than the others which have been considered above, hence it is never represented by such vast numbers of individuals as the other species. Owing to its patchy distribution over the leaf surface, it is more difficult to assess its degrees of density, but in order to bring the records for this species into line with the others the same four degrees have been employed which may be defined as follows:—If one or more individuals are present on the pinna, this is assessed as " Mark +." If the individuals are present in sufficient numbers to give a peppering to at least a portion of the pinna, this is assessed as

" Mark 1." If the peppering covers the whole pinna, or if it is especially dense over part so that some scales are only separated from each other by less than their own width, this is assessed at " Mark 2." If the density is such that most of the pinna is covered with scales which are in contact or only separated by spaces of less than their own width, then this is assessed at " Mark 3," which is, however, of very rare occurrence.

The sucking of this scale causes very little, if any, direct damage to the coconut. In fact, as the most robust trees are those which are most severely attacked, no reduction in crop can be attributed to this species. Indirectly this species causes two kinds of damage. First, the scale exudes drops of " honey-dew " which is sprayed on the foliage of the host and surrounding plants, and upon this medium a copious growth of " sooty mould " develops. Besides being very disfiguring to a plantation it must be supposed that a thick black covering to the green leaves seriously handicaps the photosynthesis of the plant. In these circumstances the tree can hardly be expected to produce its maximum yield. The amount of " sooty mould " which develops is more dependent on the humidity of the air than on the density of the scales, although of course, other things being equal, the scale density will affect the amount of " sooty mould." Under humid conditions, which may be enhanced by wet weather or by close planting in a damp environment, a very few scales may be responsible for considerable " sooty mould." Hence the reduction of this scale by controlling agents, unless it results in complete elimination, may not remove the main damage for which the species is responsible. Reduction in the humidity of the environment by attention to such factors as sufficient spacing and drainage is on the other hand more likely to bring about an improvement in conditions. A reduction in the density has, however, a beneficial effect on the second form of indirect damage caused by the present species, viz., the ant incidence. *Eucalymnatus* is one of the main scales attended by *Technomyrmex*, because this ant derives both food and shelter from this source. Food is obtained by the ant from the scale in the following manner. The ant stimulates the scale by tapping the latter with the antennae until a drop of liquid is exuded, which the ant immediately drinks. It must, however, be emphasised here that the ant also derives nourishment from scales that do not exude honey-dew, such as the DIASPIDAE. In the case of these the ant appears to feed on the waxy " bloom " or " polish " which covers the shield of living Diaspids. The ant derives shelter from *Eucalymnatus* indirectly. It collects fragments of dry " sooty mould " and with this material roofs over little crevices and corners on the leaves. In this way the ant can feed and shelter in the immediate neighbourhood of the scales. In these circumstances predacious insects work at a disadvantage, and, as will be illustrated in a later section, the control of all the coconut-infesting Coccids is handicapped by the presence of *Eucalymnatus*. A predator of *Eucalymnatus* is desirable therefore for two reasons : firstly, in order to keep the scale in check so that the work of the Diaspid predators may not be handicapped, and secondly, in order that a reduction in the scales associated with *Eucalymnatus* on coconut may not lead to an increase in the number of the latter. With this end in view it was planned from the commencement of the investigation that any Diaspid predator which might be employed in Seychelles should be accompanied by a Lecaniid predator. The Coccinellid beetle, *Exochomus ventralis*, was therefore established together with the *Chilocorus* predators of the DIASPIDAE. The extent to which the former has been effective will be considered in a later section.

Eucalymnatus is parasitised in Seychelles, but it is not certain if *tessellatus* or the very closely related *perforatum* is the true host. The coconut-feeding *tessellatus* is only very rarely parasitised, and the parasite has never been reared from coconut material. As an agent of control therefore this parasite is negligible. The entomogenus fungus, *Cephalosporium lecanii*, is an important controlling agent of *Eucalymnatus*. This fungus was recorded from Seychelles as early as 1910, and there is no doubt that its establishment is of very long standing. In 1932 a virulent strain of the same species of fungus was introduced and the establishment of this strain is claimed. Immediately following this establishment an increase in *Cephalosporium* incidence was recorded. A report on this work was published in the Annual Reports of the Department of Agriculture for the years 1932 and 1933. As this work preceded the present investigation and as the two strains cannot be differentiated in the field, the validity of the control claimed cannot be discussed here.

Importation and Distribution of Predators in Seychelles.

The search for predators in East Africa has already been noted (Vesey-Fitzgerald, 1938).

Owing to the scarcity of scales in East Africa and also the great difficulty and slowness of establishing these insects on pot plants, the advantage of exploiting the abundant supply in the Seychelles was obvious. The shipment of the selected predators to Seychelles was therefore undertaken at once, although only comparatively small numbers could be obtained.

The journey from Mombasa to Seychelles takes only three days by steamer. Connection with Mombasa from any part of the coastal districts of Tanganyika is facilitated by the local air mail service. By these means predators could be landed in Seychelles within a week of leaving the field breeding centres. A satisfactory method of shipment was as follows :—The predators were packed in small wooden boxes (about 8 in. by 5 in.) with wire mosquito gauze tops, coils of wood shavings being placed in the box to give a good foothold to the beetles. A small phial packed with moistened cotton and securely fixed inside the box provided moisture ; sufficient moisture is a most important consideration and it was found desirable, in addition, to lay thick wads of white blotting paper across part of the gauze top of the box and pin on this a request that the wad be sprinkled with water each day. Food for the Diaspid predators was provided in the form of a paste made from a mixture of yolk of egg and butter. For the Lecaniid predators a little honey was added to the mixture. The paste was smeared on sheets of clean white card which were securely pinned in an arched position against the side of the box with the paste on the lower side. By this means the beetles could crawl under the card to feed but were protected from flying into the paste and being caught with outspread wings in the sticky mass.

It is important that the beetles selected for shipment be at least several days old, for newly emerged beetles remain soft and delicate for several days and are quite unable to stand the trials of a journey. One whole shipment was lost because the beetles sent were all newly emerged. With this exception, the survival was invariably high. In the shipments of *Exochomus ventralis*, totalling 400 beetles, 93 per cent. reached their destination in good condition. In three combined shipments of *Chilocorus distigma* and *wahlbergi*, totalling 700 beetles, the percentages of living beetles which arrived were 68, 50 and 97 per cent.

Provided that sufficient and suitable food is supplied, these beetles live well in captivity. In order to breed them successfully some form of cover for their eggs must be supplied. The *Chilocorus* beetles were confined in metal glass-topped boxes with strips of palm leaves bearing living *Ischnaspis* scale for food. These boxes are very suitable for rearing of this nature because they are sufficiently airtight to prevent the too rapid desiccation of the leaf. If this takes place the leaf coils up and eggs, larvae and pupae are easily crushed. This danger can be avoided by bending the strip of the leaf round the circumference of the box so that it is unable to coil up even when dry. A fresh strip should be provided daily. The *Exochomus* beetles can be bred in the same way, using a leaf bearing Lecaniid scales or potato-shoots bearing mealy-bugs. In this case metal boxes are liable to " sweat," since both the plant and scale material are of a more juicy nature. Carton pill-boxes covered with small glass squares were found to be suitable containers in this case. Only one pair of beetles should be placed in each box, and the eggs laid should be collected each day. The resulting larvae can be reared in glass tumblers or small enamel bowls covered with muslin.

The above breeding method is useful for study purposes and for maintaining stocks, it is, however, very laborious to breed enough beetles for large scale liberation in this way. An abundant and suitable food supply is the limiting factor to mass breeding of Coccinellids. It was found to be quite impracticable to infest pot-plants with scales for feeding purposes, so that natural scale infestations had to be used. By this means the food supply is assured, but the work is decentralised and often handicapped by uncontrollable factors, such as weather, etc. The first objection is offset by the advantage that the predators are bred and established in out-districts in one move. The uncontrollable factors were gradually avoided as the technique was perfected.

The system of propagating the *Chilocorus* beetles developed as follows. In the first experiments a coconut leaf bearing living *Ischnaspis* scales was completely enclosed in a large cloth bag. The pinnae of the leaf acted as ribs to hold the bag in an extended position. The scales always occur on the lower surface of the leaf and consequently the beetles have the benefit of a large enclosed space in which to fly and an abundant food supply on which to feed and oviposit. Protection from ants was provided by a sticky band round the petiole. Ten adults were placed in each bag and breeding continued until all the scales were finished, although in practice never more than one generation was reared without moving the bag to a fresh leaf. The use of these bags was discontinued after a time for various reasons. In the first place it was difficult to clean all the ants off the leaves since they lay hidden along the grooves of the midrib of each pinna, and also the bags provided them with a very attractive shelter. A more important objection, however, was that the bags were too large and unwieldy. When the wind blew they swayed about and the leaf was in danger of being broken. During rainy weather they became sodden and the beetles and their larvae suffered. During sunny weather, especially if the bag faced east or west, they became so hot that the back of the leaf would actually turn brown.

As has been noted above, *Chilocorus* is a predator on a variety of Diaspid scales, and one abundant species, *Diaspis pentagona*, occurring on the stems of papaw was found to be a favourite prey. By making use of this scale as the food supply all the above-mentioned difficulties were avoided and mass propagation became possible. In the first place the scales formed a dense cluster round the stem, so that quite a small length of stem (about three feet), covered by a correspondingly small bag, provided ample food. The dense mat of scales also provided excellent cover for the eggs. The rigidness of the stem prevented any wind damage. The perpendicular position of the stem assured continual shade for some part of the bag as well as free drainage and quick drying after rain. Ants were easily excluded by a sticky band round the stem. In practice, the following method was adopted. Papaw trees occurred in the neighbourhood of nearly every house and hence were well and evenly distributed throughout the countryside. The islands were therefore divided into districts and every scale infested papaw located. A cylindrical bag, open down one side was arranged around each stem (Plate XII, fig. 1). The bag was tied tightly round the stem by means of running tapes at the top and bottom ends. Cane-hoops held the bag away from the stem and it was closed by clipping together the ends of the hoops and pinning the two sides of the opening together. A sticky band was put round the trunk above and below the bag to prevent the entrance of ants. Into each of these bags ten adult beetles were placed. With unvarying regularity small larvae appeared in about three weeks. At this time the bag was removed, together with the sticky bands, and the young larvae were allowed to spread and feed over the whole stem.

Some 300 papaws were employed in this way and over 25,000 beetles were established throughout the Colony. By the " papaw method " an 8-fold increase on the parents was obtained in the first generation, as compared with a 2·4-fold increase with the " coconut method." The most serious difficulty encountered was the rather frequent death of the papaw before the larvae had completed their feeding. For this reason very heavily scale-infested trees, although they offered an attractively abundant food supply, were avoided.

The subsequent development of the newly established predators proceeded with great regularity. The first generation of larvae usually finished up the scale on the original trees. From these they spread to papaws near by upon which scale was developing, but at this time rather markedly avoided other scale species. After six months, when the papaw scale had become rare in the district, a few beetles would be noticed on neighbouring coconuts. From this time onwards the spread of the predators to coconut scales accelerated rapidly, until after about one year from the date of introduction the beetles could be seen on every tree. Occasional beetles, of uncertain origin, turned up far from the points of liberation, but in general their spread was in the nature of an ever-widening circle from their point of establishment. It was, for instance, quite easy to mark a limit to their zone of activity. On one side of this limit there would be beetles on every tree, but on the other side it would be difficult to find any. This regularity persisted until adjacent districts began to overlap and from then onwards the spread became so rapid that in only a few weeks it became very difficult to find any unvisited coconut tree in Mahé Island.

The propagation of the *Exochomus* beetles followed the same lines, but certain factors peculiar to this species presented special difficulties. In the first place, the beetles are smaller and much more active ; confinement in bags was consequently more difficult. Ants were a much greater menace owing to the quantity of honey-dew and sooty-mould which was usually present on foliage attacked by Lecaniid scales. Finally, the incidence of entomogenous fungi upon the host scale became very high at certain times inside the bags. Many of these difficulties were overcome by using *Lecanium* on *Pterocarpus*. This scale was abundant and very nutritious to the beetle. The foliage of *Pterocarpus* moreover is rather open and consequently could be well ventilated, whilst the long " weeping " branches were very easily freed from ants and isolated from subsequent invasion with a sticky band. The type of bag used was of a special design. Two large hoops were sown into a cylinder of cloth, at one side of which was an inspection sleeve. This bag was slipped over the branch and tied round tightly with running tapes. In this way the escape of the beetles was prevented and the hoops holding the cloth away from the foliage increased the ventilation of the bag. A considerable number of beetles was reared in this way, but when the south-east monsoon started, it was found that these balloon-like bags became quite unmanageable in the strong wind. At this time it was found that a species of *Ischnofiorinia*, a very abundant scale on the stem of *Bambusa*, was a favourite prey of *Exochomus*. By covering this scale with a bag similar to that used on the papaw scale a very successful way of rearing *Exochomus* was arrived at. The spread of *Exochomus* was very rapid but extremely erratic. The beetles swarmed on a certain tree until the scale was finished and afterwards apparently disappeared from the neighbourhood. Their power of finding their prey is, however, remarkable, and eighteen months after their introduction this species was found in every district of Mahé.

The spread of *Exochomus ventralis* is illustrated by the following case. The beetle was first liberated at Victoria at the end of 1936. In six months it was common throughout the district. At the end of 1937 the beetle was recovered on the other side of the island at Grande Anse, a direct flight of over five miles across mountain land more than 1,500 feet high. By the middle of 1938 the beetle had crossed the sea to an uninhabited island about one mile off the coast and was found breeding on a *Lecanium* on *Ficus*. A second example of this species crossing the sea was its arrival at Long Island across a quarter of a mile of water from Cerf Island, where it was first liberated.

Life-history of Chilocorus distigma, Klug.

Egg.—The egg is elongate-oval, 1 mm. long, and of a bright yellow colour. The chorion is covered with small, regular impressions. The eggs are laid singly or in little groups, they stick to the surface on which they are laid and usually lie on one side. Whenever possible the eggs are concealed under such objects as spider's web or under the dead shield of the scale-insect, if it is sufficiently large to cover them. When no shelter is available the egg may be partly covered with fragments of dead " scales " or with the beetles own excrement. The egg hatche's 9–10 days after it is deposited.

Larva.—The full-grown larva (Plate XII, fig. 2) is pinkish or yellow, the colour varying somewhat with the nature of its food. The whole body is covered with a mealy bloom and is usually ornamented with fragments of the prey. The body, spines and tarsi are black ; head yellow. The body is obese and soft, except for a pair of small dorso-lateral areas on each thoracic segment which are slightly chitinised and lightly pigmented. Each of these areas on the prothorax is more or less triangular. The anterior margins of the prothoracic sclerites are armed with four spines. There is a fifth spine situated on each of the posterior angles. These spines are strong and relatively long (1·25 mm.) and each is armed with several strong bristles. All the remaining body segments, except the 9th and 10th, are provided with similar spines which are arranged in six rows, viz., a paired median, a lateral and an intermediate series. On the meso- and metathoracic segments the two spines of the median row are situated on the inner edge of the chitinised areas. On the 6th, 7th and 8th abdominal segments the two spines of the median row are closely adjacent at the base. The spines of the intermediate series on the meso- and metathorax are situated on the external edge of their respective sclerites. The lateral series is represented by a pair on each side of both the meso- and metathorax but by only a single spine on each side of the first eight abdominal segments. The spine of this series on the 8th segment is very small. On the 9th segment all the spines are reduced to tubercles and the 10th segment is unarmed and represented by a soft pad-like suction disc. The ventral surface of the body is also unarmed.

The larva passes through four instars. The first instar lasts for six to seven days, the second for six days, the third for five to six days, and the last instar terminates in the prepupal stage after eight to ten days. The time taken for development is, however, directly dependent on the food available, and the above periods may be taken as the optimum under conditions of ample food. The full-fed larvae tend to collect together in large numbers (Plate XII, fig. 2). They anchor themselves by the last abdominal segment, arch the back and become quiescent. This is the prepupal stage, which lasts for three days.

Pupa.—The larval skin splits down the back and opens out so as to expose part of the dorsal surface of the pupa, which, however, remains tightly enclosed in the larval skin (Plate XII, figs. 2 & 3). At the very tip of the abdomen two rod-like processes remain embedded in the larval skin of this region and provide a secure anchorage for the pupa. All parts of the pupa enclosed inside the persistent larval skin are pubescent. The colour of the exposed part of the pupa is black, but it is covered with a mealy bloom. The cornicles which are situated on each side of the first abdominal segment are chestnut-coloured. All the covered part of the pupa is chestnut. Length 0·55 cm., greatest width 0·4 cm. Viewed from above the pupa is pear-shaped. The last abdominal segment is the narrowest, the segments becoming progressively wider forwards, the region of the first abdominal and metathoracic segments being the widest part of the pupa. The head is invisible from above. The pupal period lasts for nine days.

Adult.—When freshly emerged the adult is pink, yellow or whitish, according to the nature of the food upon which the larva has fed. After a few hours the thorax becomes pigmented ; next the spots on the elytra appear ; finally, the full adult coloration is assumed. The adult beetle is shiny black with a red spot on the centre of each elytron (Plate XIII, fig. 3). The head and ventral surface are brown. Length 7 mm. The sexes are alike and are represented in approximately equal numbers.

The life of the adult probably lasts several months. The longest time an individual was kept alive in captivity was 54 days, but this period was probably rather abnormally short. Copulation takes place during the first week or ten days, and oviposition commences soon after. A female kept under observation laid 105 eggs during a period of 20 days, which gives an average of about five eggs a day. The number of eggs actually laid daily varied between 17 and 3.

Life-history of Chilocorus wahlbergi, Muls.

The egg is elongate-oval, relatively large for the size of the beetle, the length being 1 mm. and the width 5 mm. Colour dull yellow. Chorion covered with regular rather coarse impressions. The eggs lie on their sides and are often neatly arranged in a line. The incubation period is from 11 to 14 days.

Larva.—The full-fed larva is grey ; the hind margin of the dorsal surface of the metathorax, the whole of the dorsum of the first abdominal segment and the front margin of the 2nd abdominal segment, white ; dorsum of 4th abdominal segment whitish ; the whole of the 6th, 7th and 8th segments, bright yellow ; head-capsule very dark brown ; legs black. There are six equidistant rows of long, black (except those of the first abdominal segment which are white) bristles on the body. The prothorax is armed with ten bristles, six of these are arranged along the anterior margin, one on each lateral angle and a pair on the hind margin. The bristles of the lateral series on the meso- and metathorax are paired. The lateral series is unrepresented on the 7th and 8th abdominal segments. The 9th segment is unarmed and encloses the anal suction pad. The ventral surface of the abdomen is unarmed. The first stage larva is yellowish, but appears to be uniform grey owing to the relatively large and dense bristles ; the head and legs are black.

The larva passes through four instars. The first instar lasts five to six days, the second five days, the third five to six days, and the fourth terminates with the prepupa after six to seven days. The full-fed larva is not gregarious but comes to rest by itself, and after anchoring itself remains in a prepupal stage for three days.

Pupa.—In general similar to that of *C. distigma* but not so tightly enclosed by the persistent larval skin. Colour yellow-brown marked with warm brown, the whole shiny but clothed with thin yellow pubescence. Length 5 mm., width 3·5 mm. The pupal period lasts for nine days.

Adult.—The adult is shiny black without any spots on the elytra. The head is very dark brown and the underside of the abdomen and legs are brown. Length 4 mm. The sexes are alike, and males and females are equally represented. The newly emerged adult is soft and unpigmented.

The adult life is protracted, females in captivity having been kept alive for three months. One female which lived 90 days after capture laid during this period 288 eggs, which is an average of three a day. Eggs were laid on most days, the greatest number for one day being ten. Another beetle lived 65 days after capture and laid

187 eggs. The average was again three and the greatest number recorded on one day was six. A third lived 70 days, laying 164 eggs and averaging 2·3 a day, nine being the most laid on any one day.

Life-history of Exochomus ventralis, Gerst.

Egg.—The egg is elongate-oval, length 0·75 mm., colour cream. The chorion is covered with relatively large but rather shallow impressions. The eggs are laid singly, or in pairs or irregularly arranged in packets. They adhere only very loosely to the surface with which they are in contact, but are invariably tucked under some shelter such as the body of the prey or in crevices on the plant. Incubation covers five to six days.

Larva.—The full-grown larva is buff-coloured ; lateral chitinised areas on dorsal surface of thoracic segments yellow bordered with black, except the prothoracic area which is black only on the inner edge and at the extreme outside angle. Legs, median and lateral series of spines (except those on the first abdominal segment), all the thoracic spines (except the lateral ones on the metathorax), black. The prothoracic tergite is divided into two chitinised areas which are covered with setae and armed along the outside border with several small knob-like processes and at the angle with two bi- or trifid spine-like processes, each point of which is surmounted with a bristle. A pair of small chitinised areas are found on the dorsal surface of both the meso- and metathorax. The surface of these areas (as well as the non-chitinised interspaces) is armed with setae, which along the outside border of the sclerites become progressively larger and more branched backwards, each point being surmounted with a bristle. On each side of each thoracic segment there are branched spines, each branch being surmounted with a bristle. These spines are arranged in three series, viz., a paired median, a lateral and an intermediate series. The 9th segment is unarmed and the 10th is represented by a retractile suction disc. The ventral surface of the abdomen is armed with a transverse row of bristles across each segment.

The third stage larva is similar to the fourth stage except that the pale centre of the chitinised areas on the thorax are of the same colour as the body. The second stage larva has these same plates entirely black ; rarely those on the prothorax may have a light centre.

The larva passes through four instars. The first change of skin takes place three to four days after the larva hatches ; the second change in a further three to four days, the third in two to four days, and the fourth in five days. The full-fed larva comes to rest by itself anywhere on the food-plant of its prey, and on the following day the quiescent prepupa changes into the pupa.

Pupa.—The larval skin splits along the back and opens out, exposing the back of the pupa, which remains rather loosely enclosed in the persistent larval skin. The pupa is, however, quite free from the larval skin except at the point of anchorage at the very tip of the abdomen. The colour of the pupa is dirty buff, but all the exposed part is dark umber-brown ; the exposed surfaces of the pro- and mesothorax are marked with a dark square on each side, each square being framed with rich chestnut. The exposed surface of the first abdominal segment bears a yellow-brown half dumb-bell shaped mark. On each side of this segment is a forwardly directed cornicle which is yellow-brown. The exposed surface of the second abdominal segment is marked with three rather obscure chestnut dots. The remaining partly exposed segments, viz., the 3rd, 4th and 5th, are only very obscurely marked with chestnut. This pattern on the pupa is variable chiefly in the direction of an extension of the chestnut at the expense of the umber area. Total length of pupa and skin 0·45 cm., and of pupa alone 0·35 cm. The width in the region of the first abdominal segment is 0·225 cm. Viewed from above the pupa is pear-shaped, from the last abdominal segment, which is the narrowest, the width increases to the region of the metathorax and first abdominal segment. The head is invisible from above. Viewed from the side the dorsal surface is rather strongly convex and the ventral surface rather gently concave. The pupal period covers six to seven days.

Adult.—The adult life lasts at least six weeks. Copulation takes place a few days after emergence from the pupa. Females in captivity have oviposited during a period of 32 days, during which time 160 eggs were laid, giving an average of rather over five a day. About 14 was the greatest number of eggs actually deposited in one day. It is noticeable that the eggs are deposited in rhythms, which reach a peak about every six days. Towards the end of the period of oviposition the number of eggs laid during the peak periods becomes less, and days on which no eggs are produced become more frequent.

The adult beetle is shiny black without any spots or markings (Plate XII, fig. 4), the ventral surface and legs being brown. This beetle therefore closely resembles *C. wahlbergi* in appearance ; it is, however, distinguished by its smaller size (length 3–3·5 mm.), more elongate and less convex form, and greater activity. The sexes can be separated by the fact that the face of the female is black whilst that of the male is dark brown.

Life-history of Exochomus flavipes, Th.

Egg.—The eggs of this species are very similar to those of *E. ventralis*, the manner and position of laying being also similar. The incubation period covers five days, being apparently rather shorter than that of *E. ventralis*.

Larva.—The full-grown larva is similar to that of *E. ventralis* except in certain details of coloration. The outer half of the prothoracic sclerites is orange instead of yellow. The light central areas of the meso- and metathoracic sclerites is more restricted in size, on the latter sometimes completely obscured by an extension of the dusky rim. The skin, especially of the dorsal surface of the meso- and metathorax and of the 6th, 7th and 8th abdominal segments and of the whole of the ventral surface of the abdomen, is more pigmented. The paired dorsal series of spines on the abdomen are dusky but not black as on *E. ventralis*.

The first change of skin takes place three to four days after the larva has hatched, the second in a further three days, the third in another three to four days, and the prepupal stage is reached in a further four to five days. The prepupal stage lasts one day.

Pupa.—The pupa is similar to that of *E. ventralis* but may be distinguished by the characters on the persistent larval skin which have been noticed above. The marking of the exposed thorax of the pupa are also slightly different. In the present species the dark areas on the prothorax are the shape of two " L's " placed back to back, the red-brown areas being rather more extensive. Certain variations of the pupa of *E. ventralis*, however, approach this pattern and so the pupae cannot be differentiated with certainty from this character. The pupal period lasts only five days.

Adult.—The adult certainly lives over two months ; one female in captivity oviposited during a period of 69 days, during which time 284 eggs were deposited, which gives an average of four a day. As many as 27 eggs were laid on one day at the beginning of the period. The rhythm of laying appears to be sharper in this species, *i.e.* several days upon which more than ten eggs a day are laid are followed by a period when few or no eggs are laid. Towards the end of the oviposition period many blank days occur. One female at the end of its life did not lay for fourteen days and then deposited ten eggs on a single day three days before death.

The adult beetle of this species resembles *E. ventralis* in size and shape but is differentiated by a conspicuous brown area on the lateral quarters of the prothoracic tergite. The thoracic sternites and the legs are brown. The sexes are distinguished by the male having a yellow frons and clypeus, while in the female these parts are black.

Control obtained by Use of Predators.

In order to assess the degree of control obtained by the use of the imported predators, a survey of scale incidence was made both before and after the liberation of the beetles. This survey extended to include all the islands, but as the Mahé localities are the most representative and, moreover, as these places were easier to visit at stated intervals, it is sufficient for the present purpose to consider these alone.

The method adopted was as follows :—Thirteen stations scattered as regularly as possible round the island were selected. In most cases two samples were taken at each station : one sample at or near sea-level, and the other in the mountains behind. In certain places where two different soil types abutted one another, as for instance the coral sand and alluvium at Anse-aux-Pins, one sample was taken from each. In this way 22 samples were taken which are fully representative of the coconut plantations of the island. Each sample consisted of one pinna cut in the order of age from every leaf of five trees. Each pinna was examined and the density of each species of scale was recorded according to the degrees of density already defined. The percentage of leaves in each sample which showed each degree of density was recorded under the respective " Mark."

Each station was visited three times, and so far as possible the same trees were sampled each time. The 1937 sample was taken before any predators were liberated, and so this figure represents the original scale density. The 1938 sample was taken six months to one year after the predators had become established in the district. The 1939 sample was taken another six months later, immediately prior to the close of the investigation. The result of each year's samples for each species are presented in the form of tables.

Table I illustrates the control of *Ischnaspis*. The 1937 count emphasises the severity of the original incidence of this species. Up to one-third of the leaves in two samples gave a " Mark 3 " density and in 13 out of the 22 samples this density occurred on over 10 per cent. of the leaves. Moreover, in several cases where the " Mark 3 " density is represented by a low figure for this species, either the *Chrysomphalus* or the *Pinnaspis* density is high. In only one sample, that at Anse-aux-Pins on coral sand, is a low incidence explained by soil conditions (see discussion of ecology of *Ischnaspis* above). The 1938 sample, taken after the liberation of the predators, shows a very marked reduction in scale density. In this count in only four samples do " Mark 3 " infested leaves exceed 10 per cent. In only one sample, that at Anse Boileau, has there been a marked increase in *Ischnaspis* density, and at this locality the predators had only just become established at the time of the sampling. The 1939 count shows a continuation of the reduction of *Ischnaspis*. In this count no sample shows a 10 per cent. " Mark 3 " incidence, in fact " Mark 3 " is only represented in three samples. On the other hand, it will be noticed that there is a constant increase in the number of leaves upon which the lighter densities are recorded, which may be taken as evidence that it is in fact the predators which have brought about the reduction in scale incidence and not a general waning of attack. If the attack was dying out, the " Mark 1 " and " Mark + " leaves, which represent leaves on which young scales are settling and commencing to grow and breed, would become reduced in number. The " Mark 3 " leaves would, on the other hand, still be recorded, until the dead leaf fell from the tree, because the scales which die remain adhering to the leaves. Hence the " Mark 3 " figure would remain relatively high and the " Mark 1 " and " Mark + " figure low. The predators on the other hand feed most freely on the leaves where the greatest number of living scales are concentrated. Hence, while a leaf is at only " Mark + " or " Mark 1 " they may overlook it, but as soon as " Mark 2 " is approached the predators appear in numbers. Hence it is obvious that an attack which is being controlled by the predators is represented by a relatively high proportion of " Mark + " or " Mark 1 " leaves. A count at a later date would no doubt show a further reduction of incidence, but at the same time it is suggested that somewhere about the limit of control has been reached in most cases. It seems probable for many reasons, some of which will be mentioned in connection with other species of scales, that a sort of balance will be set up between predators and scales around a degree of density not above " 20 per cent. Mark 1 plus 50 per cent. Mark +." It will be noticed that many of the *Ischnaspis* samples are approaching this figure in the 1939 samples. Scales at this density are well below the point at which they cause economic loss.

Table II illustrates the effect of the predators on *Pinnaspis*. In the first place the 1937 count shows the uneven distribution of this species. In five of the twenty-two samples it is not represented at all, and in ten others the density never exceeds " Mark 1." In four samples, however, the density reaches " Mark 3," in one case 45 per cent. of the leaves supporting this density. The 1938 count gives eight samples with no *Pinnaspis* and nine in which the density does not exceed " Mark 1." Of the four bad samples, three show a reduction in density, although only at Mamelle is this reduction marked. The fourth sample, that from Anse Boileau, shows an increase in *Pinnaspis* incidence, but, as was explained under the *Ischnaspis* sample, the predators had only just been liberated in this district when the sample was taken. In the 1939 count *Pinnaspis* is recorded in all except two of the samples, but in fourteen of the samples in which it is present the density does not exceed " Mark 1." A reduction in density is recorded for the badly infested samples. At Anse Forbans there has been a rise in incidence. These figures show that during the three years there has been a reduction of scale density in the serious outbreaks, but at the same time a general increase in the distribution of the pest. In order to assess the degree of control which can be claimed these two conflicting facts must be explained. It is characteristic of a *Pinnaspis* outbreak that in restricted localities a high percentage of the leaves of all the trees are severely attacked. The outbreak is not usually of very long duration ; it dies down naturally, and eighteen months after the death of the scales, when the tree has had time to replace its blighted leaves, all sign of the infestation may have gone. In the circumstances the period of observation is too short and the number of samples too limited for it to be unconditionally claimed that the reduction in the severe incidence noted in the 1938 and 1939 counts is entirely due to the work of the predators. However, it will be noticed that the characteristics of a " predator controlled " outbreak as opposed to a " naturally dying " outbreak, which have been explained under *Ischnaspis*, are beginning to become evident. There is a progressive reduction in the higher " Mark 3 and 2 " densities and at the same time a slight, but not inconclusive, rise in the lighter " Mark 1 and + " densities. Observations over a longer period of time alone can prove or disprove the effectiveness of the predators against *Pinnaspis*. The second fact noted, namely, the general increase of *Pinnaspis* incidence, must next be considered. It has been indicated earlier that before the predators commenced their work competition for space between the coconut scale species was severe. This competition was especially acute between *Ischnaspis* and *Pinnaspis*. The great reduction in *Ischnaspis* caused by the predators would therefore allow space for a corresponding increase in *Pinnaspis*. It seems in fact that the disappearance of *Ischnaspis* is directly responsible for the increase in *Pinnaspis* incidence which is noted in the 1939 count. Again, time alone can show what the ultimate result will be. If by any chance *Pinnaspis* was not effectively controlled by the predators and as a consequence replaced *Ischnaspis*, a new problem would arise. It will be noted, however, that the fresh 1939 appearances of *Pinnaspis* are of a certain type. Setting aside the samples in which this scale is only recorded from a very low percentage of leaves at " Mark +," which may be considered as incipient incidences, the *Pinnaspis* density of the majority of the samples stands around " less than 10 per cent. Mark 1+20–40 per cent. Mark +." Granted therefore that a reduction in *Ischnaspis* allows for an increase in *Pinnaspis*, the new *Pinnaspis* density under the influence of the predators is apparently settling down to a figure resembling that of the new *Ischnaspis* density, which has been noted above. By comparison, therefore, it may be surmised that *Pinnaspis* is in fact being held in check by the predators. At the above density this scale is below the level for causing economic damage.

Table III shows the effect of the predators on *Chrysomphalus ficus*. Owing to the somewhat patchy distribution on the tree of the scale, especially of the higher densities, its incidence at the various densities is much more difficult to assess. Owing to an early imperfection of the method employed it will be noticed that the " Mark 3 and 2 " densities of the 1937 count are not differentiated in the majority of cases, but are recorded together under " Mark 3." With these reservations, however, the table gives an accurate representation of the facts as affecting this species. It will be noticed, for the 1937 count, that *Chrysomphalus*, like *Pinnaspis*, only appears in outbreak form in a limited number of localities. " Mark 3 " is reached ten times, but in only three of these cases does it reach or exceed 10 per cent. of the leaves. On the other hand, this species is recorded up to " Mark 1 " in every sample, which emphasises its very wide distribution. In the 1938 count, a general, but not very marked, reduction can be noticed. This time " Mark 3 " is reached only twice and each time only 1 per cent. of the leaves showed this density. This species is still recorded from every sample. In the 1939 count, however, the reduction has not been maintained ; " Mark 3 " is now reached twice. Setting aside for the time these two samples, it will be seen that in fifteen cases there has been a reduction on the 1938 count, and in nineteen cases on the 1937 count, as opposed to four cases and one case which show increases on the 1938 and 1937 counts respectively. Therefore there is a balance in favour of the control of *Chrysomphalus* by the predators. Further, in seven of the 1939 samples the density never exceeds " Mark + " and is therefore negligible, and in eleven of the remaining samples the density shows a tendency to be settling down to a density figure round " less than 10 per cent. Mark 1+20–40 per cent. Mark +," which, as has been explained above, appears to be a hypothetical predator-scale balance. The Bay Lazare sample, which shows a progressive reduction during the three years under consideration, may be expected to arrive at this same balance in time and is therefore not exceptional. The two exceptional samples which must now be considered are Glacis 100 and Anse Baleine 50. Both these samples showed a severe incidence in 1937, and in both cases this was noticeably reduced in the 1938 count. The 1939 count, however, shows a fresh increase in the density.

Turning back to Table I, it will be seen that these two samples also show an increase in *Ischnaspis* density for the 1939 count. The explanation for these facts can be found by reference to Table IV, where it will be seen that in both these localities there is a comparatively high density of *Eucalymnatus*, which has caused a local concentration of the ant, *Technomyrmex*, which handicaps the work of the predators. It has been proved that the predators can, in normal circumstances, reduce the density of *Ischnaspis*. Increase of *Chrysomphalus* in the same circumstances which are also allowing an abnormal increase of *Ischnaspis* need not, therefore, be taken as evidence that the predators are not also able to reduce this pest. To sum up, therefore, figures presented in Table III indicate that the density of *Chrysomphalus* is also being reduced as a result of the establishment of the imported predators, and as a corollary it may be added that the table shows no evidence that the incidence of *Chrysomphalus* will increase as a result of the reduction of competition between this species and *Ischnaspis*.

Table IV shows the effect produced on *Eucalymnatus tessellatus*. Theoretically the *Exochomus* beetles are the chief predators of this species, but it is apparent in the field, when this scale is mixed with the other species, that adult *Chilocorus* beetles consume a large number of individuals of this species.

The 1937 figures show that this species was present in densities up to " Mark 1 " in every sample, but in only three cases were greater densities represented. In 1938 the scale was represented by only " Mark + " in three cases, but densities greater than " Mark 1 " were recorded from seven localities. This, therefore, represents an increase in the population of this species. In 1939 the number of times that this species was represented by only " Mark + " rose to eight, and at the same time the number of times at which densities greater than " Mark 1 " are recorded dropped to five times, and in three of these only 1 per cent. of the leaves are recorded with a " Mark 2 " density. This represents, therefore, a very marked reduction in the incidence of this species. It has been stated above that the presence or absence of entomogenous fungi is of first importance in causing a fluctuation in the population of *Eucalymnatus*. The incidence of these fungi varies with weather conditions, and actually the years under consideration have been dry. The fungi have, as a consequence, been at a rather low ebb, and their incidence may be considered as constant during the period. The effect of the predators may be somewhat masked by the fungi, and so their influence may be best assessed by turning from the general to the particular. At Mamelle the *Exochomus* and *Chilocorus* predators were bred in large numbers, and the very noticeable reduction of *Eucalymnatus* recorded from the sea-level sample at Mamelle was directly due to their work. At Cascade sea-level and Anse Boileau sea-level, the declining density is correlated with the presence of *Exochomus*. At all other localities where the density has been reduced other scales have also been reduced and *Chilocorus* has been present. At Glacis 100, Anse Baleine 50, Anse la Retraite 50, where a marked increase or maintenance of density is noticeable, predators have been scarce, the reduction of the other scales has been slow or held up, and *Technomyrmex* has been particularly abundant. To sum up the position of *Eucalymnatus*, therefore, although no conclusive proof of control can be produced, available evidence strongly indicates that the predators are favourably influencing the decrease in the density of this scale which is noticeable in the 1939 count. There is some suggestion in the figures of Table IV that *Eucalymnatus* density is settling down to a predator-prey balance around " less than 50 per cent. Mark +." This figure is deduced because in every sample with only " Mark + " represented the percentage of leaves attacked are around 50 per cent. or below and in every sample where more than 50 per cent. " Mark + " leaves are present, some " Mark 1 " leaves are also present, and in every sample where " Mark 1 " leaves are present a fluctuation in density, usually a progressive reduction, is noticeable. This balance is comparable to that suggested for other species, since the individual scale is larger in size, and therefore " Mark + " for *Eucalymnatus*, regarded from the point of view of " predator attractiveness " is more equivalent to a " Mark 1 " of the other species. As a corollary to this general reduction in density it may be noted that no sign of *Eucalymnatus* benefiting from the reduced competition with *Ischnaspis* is indicated.

TABLE I.

Assessment of Control of Ischnaspis longirostris.

Locality	Bel Ombre 50′				Bel Ombre 300′				Mamelle sea-level				Mamelle 300′				Cascade sea-level				Cascade 200′				Glacis 100′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	26	12	37	18	33	23	21	15	20	20	43	8	25	12	31	23	2	14	52	17	21	16	39	12	6	7	37	30
1938	4	8	43	33	16	21	35	15	8	17	30	15	10	11	33	23	1	2	27	35	9	15	38	22	—	1	32	40
1939	—	1	40	48	5	19	24	37	—	—	16	53	—	—	6	75	—	—	9	51	—	2	24	67	1	3	31	44
Locality	Glacis 300′				Anse Baleine 50′				Anse Baleine 500′				Anse la Retraite 50′				Anse la Retraite 500′				Anse Forbans sea-level				Anse Dejeuner 50′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	16	23	29	22	—	—	20	49	16	21	37	22	2	10	51	27	—	—	60	28	18	7	50	20	24	8	34	20
1938	11	18	33	24	—	—	9	76	—	12	34	31	2	3	28	51	—	7	32	51	9	11	60	13	16	11	33	25
1939	—	12	20	46	1	—	11	46	—	2	18	55	—	—	31	49	—	—	39	50	—	4	23	54	—	2	15	53
Locality	Anse Dejeuner 500′				Bay Lazare 400′				Anse Boileau sea-level				Anse Boileau 400′				Anse aux Pins sea-level (coral sand)				Ans aux Pins sea-level (alluvium)				Anse la Mouche sea-level			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	1	6	22	58	6	12	52	22	33	17	25	17	30	12	44	12	—	4	37	43	11	17	51	14	16	26	32	9
1938	2	8	41	26	—	—	35	50	44	21	15	9	2	20	53	17	—	1	10	43	7	8	52	22	4	19	52	18
1939	—	4	21	62	—	—	16	54	—	19	24	30	—	14	48	30	—	—	1	60	0	1	29	54	—	2	26	61

TABLE II.

Assessment of Control of Pinnaspis buxi.

Locality	Bel Ombre 50′				Bel Ombre 300′				Mamelle sea-level				Mamelle 300′				Cascade sea-level				Cascade 200′				Glacis 100			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	2	2	—	—	—	1	7	4	4	5	—	—	1	3	—	—	—	—	—	—	1	17	—	—	—	—
1938	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
1939	—	—	—	15	—	—	7	26	—	—	1	22	—	—	3	41	—	—	—	—	—	—	5	36	—	—	—	1
Locality	Glacis 300′				Anse Baleine 50′				Anse Baleine 500′				Anse la Retraite 50′				Anse la Retraite 500′				Anse Forbans sea-level				Anse Dejeuner 50′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	8	8	—	—	—	—	—	—	5	11	—	—	1	3	45	18	17	10	—	—	20	17	—	—	—	—
1938	—	—	3	19	—	—	—	—	—	—	—	2	—	—	2	4	24	30	13	7	—	—	—	3	—	—	—	—
1939	—	—	15	35	—	—	—	—	—	—	5	7	—	—	4	25	—	14	38	29	1	3	24	28	—	—	4	28
Locality	Anse Dejeuner 500′				Bay Lazare 400′				Anse Boileau sea-level				Anse Boileau 400′				Anse aux Pins sea-level (coral sand)				Ans aux Pins sea-level (alluvium)				Anse la Mouche sea-level			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	1	—	7	5	3	13	33	13	—	—	—	—	6	7	55	18	—	—	—	1	—	1	5	3	—	—	6	5
1938	—	3	4	19	2	11	50	27	—	—	—	—	30	40	16	10	—	—	—	8	—	—	—	2	—	—	—	9
1939	—	1	11	29	—	4	61	29	—	—	—	1	3	10	20	33	—	—	—	2	—	—	7	38	—	—	3	25

TABLE III.

Assessment of Control of Chrysomphalus ficus.

Locality	Bel Ombre 50′				Bel Ombre 300′				Mamelle sea-level				Mamelle 300′				Cascade sea-level				Cascade 200′				Glacis 100′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	12	39	—	—	5	18	3	—	11	28	—	1	2	45	—	—	33	25	—	—	7	45	22	10	21	17
1938	—	3	10	33	—	—	—	10	—	—	—	13	—	3	—	17	—	—	2	19	—	—	—	12	—	7	17	38
1939	—	1	3	31	—	—	4	25	—	—	—	10	—	—	4	13	—	—	1	13	—	—	2	37	3	15	14	34
Locality	Glacis 300′				Anse Baleine 50′				Anse Baleine 500′				Anse la Retraite 50′				Anse la Retraite 500′				Anse Forbans sea-level				Anse Dejeuner 50′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	10	23	20	7	8	21	—	1	6	38	—	—	14	37	2	—	40	42	4	—	24	47	—	—	3	29
1938	—	—	4	18	—	13	14	43	—	—	—	3	1	7	12	30	1	7	21	33	—	—	5	40	—	—	—	19
1939	—	—	—	10	1	3	13	41	—	—	—	12	—	—	4	31	—	—	10	38	—	—	—	12	—	—	4	31
Locality	Anse Dejeuner 500′				Bay Lazare 400′				Anse Boileau sea-level				Anse Boileau 400′				Anse aux Pins sea-level (coral sand)				Ans aux Pins sea-level (alluvium)				Anse la Mouche sea-level			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	3	23	10	—	40	32	4	—	33	31	6	—	43	27	1	—	6	47	1	—	17	35	—	—	7	28
1938	—	—	2	16	—	19	46	28	—	—	5	22	—	7	44	38	—	—	1	9	—	—	2	37	—	—	1	53
1939	—	—	1	12	—	1	30	58	—	—	—	2	—	1	7	22	—	—	—	9	—	—	—	18	—	—	1	9

TABLE IV.

Assessment of Control of Eucalymnatus tessellatus.

Locality	Bel Ombre 50′				Bel Ombre 300′				Mamelle sea-level				Mamelle 300′				Cascade sea-level				Cascade 200′				Glacis 100′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	50	28	—	—	23	29	—	5	70	8	—	—	34	44	—	—	66	18	—	—	1	55	—	—	60	17
1938	—	7	31	53	—	—	2	41	—	—	16	44	—	—	23	40	—	1	11	38	—	—	5	49	—	10	52	23
1939	—	—	9	76	—	—	—	24	—	—	1	43	—	—	2	70	—	—	—	33	—	—	1	61	—	8	39	42

Locality	Glacis 300′				Anse Baleine 50′				Anse Baleine 500′				Anse la Retraite 50′				Anse la Retraite 500′				Anse Forbans sea-level				Anse Dejeuner 50′			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	49	29	2	—	64	15	—	—	4	41	—	—	64	18	—	—	2	31	—	1	52	25	—	—	42	43
1938	—	1	19	52	—	4	17	79	—	—	—	10	—	9	46	32	—	—	—	14	—	—	5	78	—	—	8	58
1939	—	—	—	51	—	4	17	59	—	—	—	15	—	1	7	67	—	—	—	48	—	—	—	20	—	1	1	69

Locality	Anse Dejeuner 500′				Bay Lazare 400′				Anse Boileau sea-level				Anse Boileau 400′				Anse aux Pins sea-level (coral sand)				Anse aux Pins sea level (alluvium)				Anse la Mouch sea level			
Mark	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+	3	2	1	+
1937	—	—	11	52	—	—	27	34	—	—	36	34	—	—	15	35	—	—	23	45	—	—	52	32	—	—	37	33
1938	—	4	36	37	—	—	4	65	—	—	21	51	—	—	—	24	—	—	5	31	—	—	40	43	—	—	13	77
1939	—	1	1	69	—	1	1	50	—	—	—	21	—	—	1	36	—	—	—	11	—	—	1	69	—	—	2	72

Summary.

1. The investigation which forms the subject of this paper was commenced in 1936 and closed in 1939. Owing to the low returns from an acre of coconut land it was imperative that control measures should be cheap. Biological methods were therefore employed.

2. The soils on which coconuts are planted in Seychelles fall into three main types: (*a*) beds of coral sand, (*b*) various types of transported soils, (*c*) sedentary soils.

3. The robustness of the trees was found to be in direct proportion to the quality of the soil. The best trees are located on the deeper alluviums. The limiting factor on the coral sands is often drainage. On the hill-sides the trees deteriorate in proportion to the soil impoverishment and erosion.

4. A complex of scale species attack coconuts in Seychelles. None of these presents major problems in other countries, and the better known scales which are pests on this crop in other countries are not found in Seychelles. Four major species are mentioned, two of which are recent introductions to the islands. The life-history and particular requirements of each species are given and their incidence on coconut and their interspecific relationships are discussed.

5. In order to combat these scales four species of COCCINELLIDAE were introduced from East Africa, two of which were predators on Diaspid and two on Lecaniid scales. The life-history, breeding technique and establishment of each is described.

6. Records covering three years are submitted to illustrate the effect of these predators on the scale population. These records show that the predators are reducing the scales below the density at which they cause economic loss and also support the view that the reduction of one species is not being followed by the increase of another.

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EXPLANATION OF PLATE XI.

Fig. 1.—*Ischnaspis* scales on lower surface of coconut leaf at density " Mark +."

Fig. 2.—The same at density " Mark 1."

Fig. 3.—The same at density " Mark 2."

Fig. 4.—*Chrysomphalus* scales on lower surface of coconut leaf. The large scales are those of the females and the more numerous small ones are those of the males.

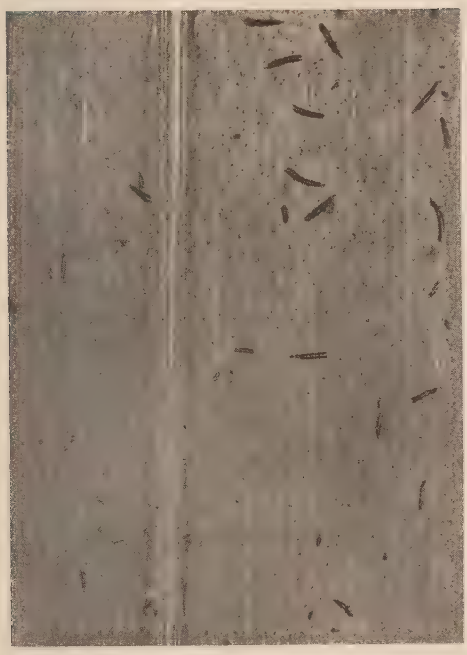
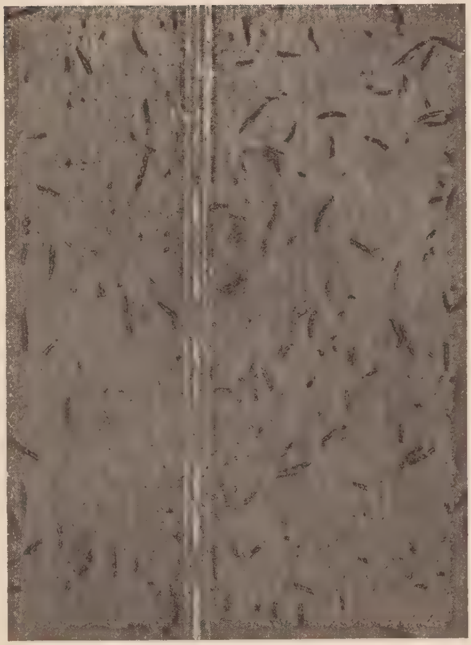


Fig. 1.



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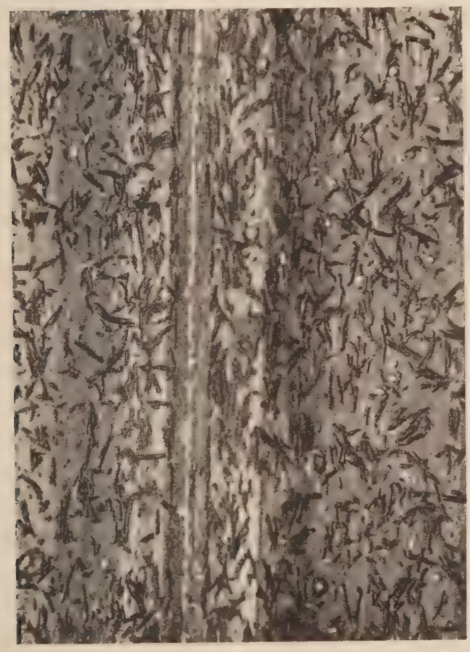

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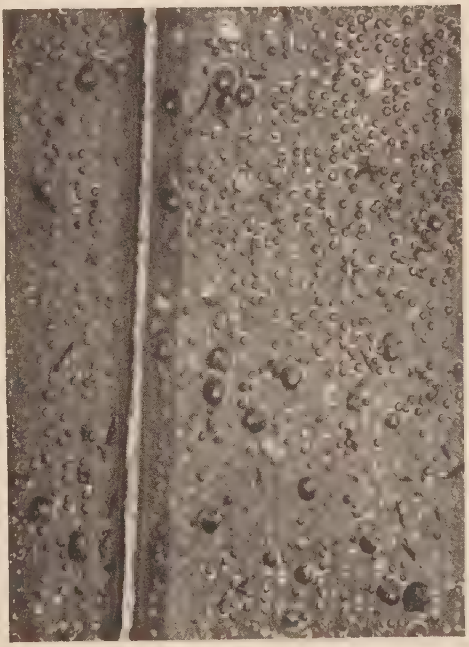


Fig. 4.

Coconut-feeding Coccids and their Coccinellid enemies.

EXPLANATION OF PLATE XII.

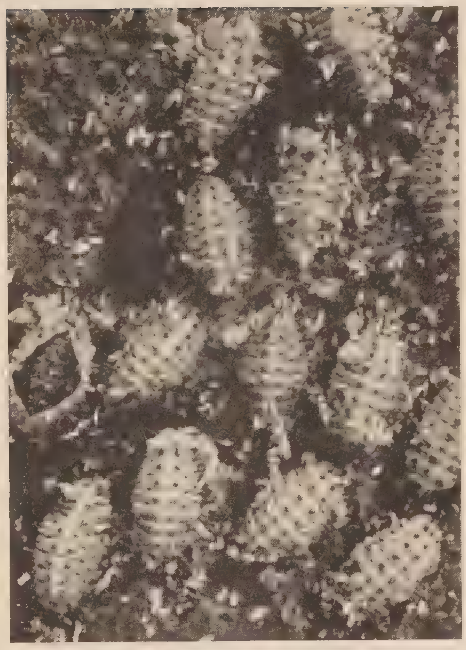
Fig. 1.—Bag on scale-infested trunk of papaw, used for the breeding of *Chilocorus distigma*. Note the sticky bands round the trunk above and below the bag to stop the entry of the ant *Technomyrmex*.

Fig. 2.—Full-fed larvae of *Chilocorus distigma* clustered ready to pupate. Note the pupa at the left side.

Fig. 3.—Adults and empty pupae of *Chilocorus distigma* on leaf of coconut bearing *Ischnaspis* scales.

Fig. 4.—*Eucalymnatus tessellatus* on the lower surface of a coconut leaf being attacked by *Exochomus ventralis*. The scales which show up white have been killed by the fungus *Cephalosporium lecanii*.

Fig. 1.



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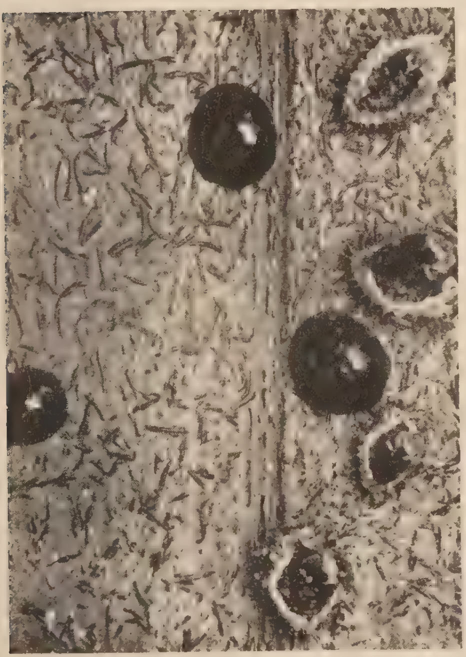

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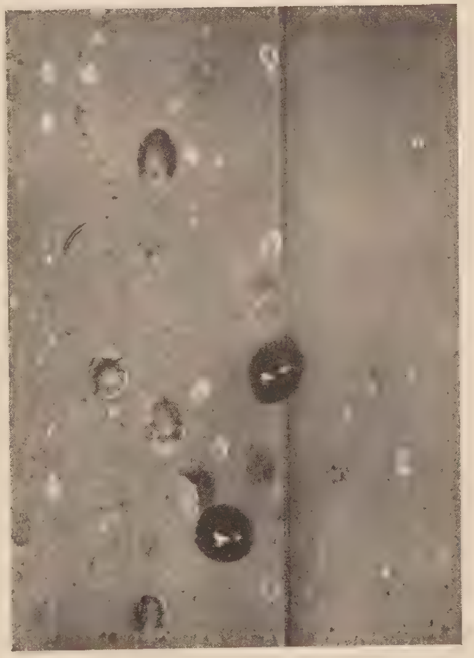

Fig. 4.

Coconut-feeding Coccids and their Coccinellid enemies.

SECOND SURVEY OF THE WOOD-DESTROYING INSECTS IN PUBLIC BUILDINGS IN SWEDEN.

By Ivar Trägårdh.

Entomological Department, Royal Swedish Institute of Experimental Forestry.

In Vol. 29 (March, 1938) of this jourual a short summary was given of the results achieved during an investigation of the wood-destroying insects in public buildings in the southern part of Sweden, Götaland. This survey has since that time been continued in Svealand, the middle part of Sweden, and in the following a short summary of the results will be given.

The investigation proceeded along the same lines as before: an illustrated leaflet, containing short descriptions of the insects in question and their galleries, was issued together with a detailed questionnaire and a circular letter and was sent to about 45,000 persons.

Altogether 1,801 reports were returned, 789 of which gave fairly detailed information on the questions asked, and often were accompanied by samples of wood for identification of the damage. The percentage of buildings in which injuries of insects were recorded was nearly the same as in Götaland, or 43·8 per cent. as compared with 46·1 in Götaland. The same insects were reported, *viz.*, *Hylotrupes bajulus*, L., *Callidium violaceum*, L., *Ernobius mollis*, L., and *Anobium striatum*, Oliv., dominating, while *Monochamus sutor*, L., and *Sirex* sp. occurred more rarely.

The earlier survey presented the striking feature that the counties round the coasts were infested on the average twice as much as those in the interior. When discussing this phenomenon I put forward several suggestions: " Assuming that the timber in the different counties was produced in the forest of the same counties, the fact that the forests in the maritime counties grow more rapidly, the timber having as a consequence larger annual rings, thus being softer, may account for the difference, it being a well-known fact that the insects prefer quick-growing timber." This explanation must, however, be discarded, because Scania is not self-supporting as to timber, but imports a great deal from Smàland, where the lowest percentages are recorded (21·6 and 25·9).

Granted that the most injurious of these insects (Group III) spread from building to building and from village to village, a greater density of the population must facilitate the distribution to such an extent that the infestation becomes more severe in the densely populated parts. As a matter of fact there is a very good correlation between the density of the population and the frequency of the attacks.

The mean number of the population in the coast zone is 50·2 inhabitants per square km., in the other zone 25·5, the respective percentages of houses attacked being 49·8 and 25·6. Thus the possibility that there is a causal connection between the density of the population and the frequency of attack must not be overlooked.

Finally, there is the possible influence of climatic conditions to be considered, although admittedly it is impossible to gauge their effect on insects in houses by using the generally adopted method of constructing climograms. For the same reason the investigation was restricted to the temperature, and more particularly the mean temperature, of the coldest month, February, and the yearly mean temperature. We notice that the former is only −1·25° Celsius in the coast zone but −3·08° Celsius in the inland zone, the mean annual temperature being in the coast zone +7·11° Celsius and in the inland zone about +5·4° Celsius.

Until experimental evidence exists regarding the influence of different temperatures on the viability and development of these insects it is impossible to draw any conclusions from these data.

The influence of humidity was not considered in this survey, but subsequent researches in Germany have revealed the fact that greater humidity of the air is favourable to the development of *Hylotrupes*.

The results of the present investigation tally with those of the first survey (fig. 1). The counties of Stockholm and Uppsala have a percentage of 52 and 54·7, the remaining counties not exceeding 40 per cent. and the mean percentage of all counties being 33·33. The only exception is the county of Södermanland with a percentage of 26·4. Very remarkable is the heavy infestation in Gotland, an island in the Baltic Sea, where the percentage amounts to 92·7 per cent.

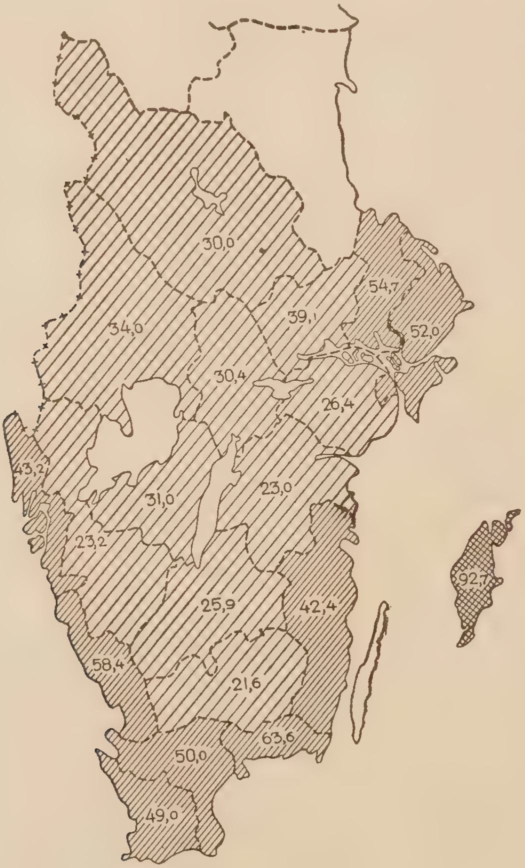

Fig. 1. Map of southern and middle Sweden, showing the percentage of Government buildings reported as attacked by wood-destroying insects. (Compare Table.)

Since my first report was published (1935) Danish and German entomologists have made extensive experiments, especially on the influence of the humidity of the air and of the temperature on the development of *Hylotrupes bajulus*.

It may now be considered an established fact that an air humidity of 90–95 per cent. is favourable to the propagation of this insect in so far as the mortality of the eggs is lowered and the larval development is accelerated.

Before discussing the more detailed data given in Table I it is necessary to touch briefly on the biology of the different species with special regard to its influence on the mode of spreading, which itself must form the basis of preventive measures:—

Group I.—Passive intruders which in the larval or pupal stage are introduced into the houses in the timber and complete their development but are unable to propagate in the houses. The source of infestation is the forest, and its cause is the practice of sometimes leaving undecorticated trees or logs in the forest during summer.

This group embraces *Monochamus sutor* and several species of *Sirex* and occurs comparatively rarely.

Group II.—Passive intruders, the larvae of which tunnel under the bark and are introduced into the houses at the time of building, if bark is left on the timber. The source of infestation is generally saw-mills and timber yards. This group embraces *Callidium violaceum* and *Ernobius mollis*, which may both continue their breeding in the houses for some years, provided that there is enough uninfested timber with bark left on it.

Group III.—Permanent active intruders, living in the wood, which attack the houses generally many years after they have been built. This group embraces *Hylotrupes bajulus* and *Anobium striatum.*

In Table I the results of the survey are given, arranged according to counties and categories of buildings, viz., churches, public buildings, dwelling houses and outhouses. In the previous survey the last-named category was not included because the data were not considered reliable, less attention having been paid by the officials to the economically relatively unimportant outhouses. The data from Svealand are, on the other hand, more reliable.

TABLE I.

The Number of Government Buildings reported as attacked in Svealand.

+=attacked; 0=not attacked.

County	Churches			Public buildings			Dwelling houses			Outhouses			All buildings		
	+	0	%	+	0	%	+	0	%	+	0	%	+	0	%
Stockholm	32	68	32·0	13	24	35·0	96	108	47·0	102	24	80·9	243	224	52·0
Uppsala ...	23	47	32·0	8	11	42·0	47	34	58·5	45	10	81·8	123	102	54·7
Södermanland	13	72	15·3	2	6	25·0	30	73	29·0	12	8	60·0	57	159	26·4
Västmanland	7	22	24·1	3	1	75·0	19	33	35·7	7	—	100	36	56	39·1
Örebro ...	7	43	14·1	2	15	11·7	26	79	24·7	35	23	60·0	70	160	30·4
Kopparberg	1	12	7·7	4	7	36·3	17	36·3	22·2	11	8	57·8	33	85	30·0
Värmland ...	12	61	16·4	2	17	10·5	49	123	28·4	49	16	75·4	112	217	34·0
Gotland ...	35	3	92·1	—	—	—	44	4	91·0	36	2	94·7	115	9	92·7
	130	328	28·3	34	81	29·5	328	512	39·0	297	91	73·9	789	1,012	43·8

The figures representing the mean percentage of attacked buildings in Götaland (*l.c.* Table I, p. 58) and Svealand, 40·5 per cent. and 43·8 per cent., seem to agree very well. But it is necessary to make two corrections if the figures are to be compared.

In Table I for Götaland (*l.c.* p. 58) the outhouses are omitted, because the data for the different counties were too few to be considered reliable. In Svealand these data were sufficient and the mean percentage of attack being very high, the total mean percentage is accordingly increased. If this category is omitted the total mean percentage is not 43·8 but 39·7. This does not imply that the figure obtained from Svealand, 43·8 per cent., is faulty, only that it cannot be compared with the figure 40·5 from Götaland, because this figure is too low.

Another correction must also be made for Gotland, because this island does not belong either to Götaland or Svealand but represents from the point of view of wood-destroying insects a special province.

After these two corrections have been made a comparison between the two provinces is given in Table II.

TABLE II.

Comparison between Götaland and Svealand as regards the Percentage of attacked Buildings, after Gotland and the Outhouses have been omitted from Svealand.

	Churches	Public buildings	Dwelling houses	All buildings
Götaland	34·7	40·1	43·6	40·5
Svealand	22·6	29·5	35·0	31·3

From this it is evident that the infestation is less frequent in Svealand than in Götaland, and this applies particularly to the churches.

The heavy mean infestation in Gotland, 92·7 per cent., is not due to any particular category of buildings being preferred, churches, dwelling houses and outhouses having a percentage of above 90 per cent. This being the case, it is difficult to believe that the reports of the non-existence of attacks in public buildings are true.

TABLE III.

The Frequency of the different Insects in different Buildings.

	Churches		Public buildings		Dwelling houses		Out-houses		All buildings	
	Götaland	Svealand	Götaland	Svealand	Götaland	Svealand	Götaland	Svealand	Götaland	Svealand
Hylotrupes bajulus	16·6	20·0	28·0	32·4	15·2	19·8	11·7	37·0	15·8	26·9
Anobium striatum	72·9	55·4	53·0	23·5	66·2	43·3	72·7	55·2	68·1	48·9
Ernobius mollis	19·6	33·1	39·0	32·4	44·7	40·2	43·6	31·0	38·8	35·2
Callidium violaceum	7·5	24·6	22·0	55·9	25·9	37·8	23·4	42·4	21·1	38·1
Other species	28·1	8·5	10·0	5·9	7·6	4·9	5·7	6·4	11·4	6·1

Table III shows the percentage of the different species in the attacked buildings. From this it is evident that *Hylotrupes bajulus* does not show any tendency to become more scarce in Svealand than in Götaland, rather the reverse (15·8 compared with 26·9 per cent.). The same applies to *Callidium violaceum* with a frequency of 21·1 per cent. in Götaland against 38·1 per cent. in Svealand. *Anobium striatum*, on the other hand, is more scarce, while *Ernobius mollis* is about as common in Svealand as in Götaland.

TABLE IV.

Distribution of the Attacks of Hylotrupes *and* Anobium striatum *in different Parts of the Buildings.*

Roof timber		Floor of attics		Other floors		Walls		Furniture and wood work		Total	
Göta-land	Svea-land	Göta-land	Svea-land	Göta-land	Svea-land	Göta-land	Svea-land	Göta-land	Svea-land	Göta-land	Svea-land
70·8	76·4	21·9	16·3	23·9	19·3	26·6	34·0	28·8	18·0	12·9	8·7

Table IV and fig. 2 give the result of a comparison between Götaland and Svealand as regards the frequency of *Hylotrupes bajulus* and *Anobium striatum* in different parts of the buildings. It is of great interest to learn that the figures giving the frequency of the permanent pests in the roof timber are almost the same in Götaland and Svealand. It can now be regarded as a positive fact that also in Sweden the roof timbers are more exposed to attacks from *Hylotrupes bajulus* and *Anobium striatum* than any other parts of the buildings.

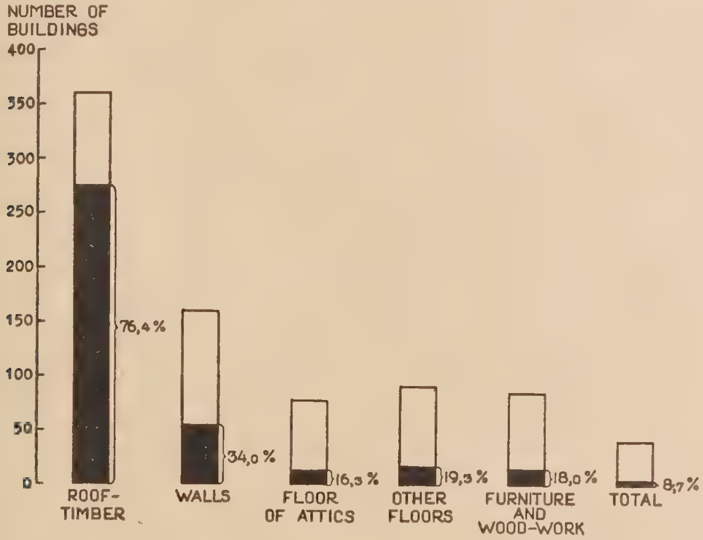

Fig. 2. Frequency of *Hylotrupes* and *Anobium striatum* in different parts of the buildings.

This being the case it is of interest to see whether the frequency of attack is affected by different roofing materials, which may have an influence in two ways, partly through their colour and partly through their lesser or greater density. The timber under dark roofs grows hotter through insolation, while roofs of a more porous material facilitate ventilation, which tends to keep down the temperature. The investigation of Götaland (*l.c.* fig. 2) elicited the fact that houses with iron roofs were most attacked (21·3 per cent.), whereas houses with tile roofs had only a percentage of 12·2 and those with roofs of tar-paper or slate were also comparatively little attacked (14·8 and 13·7 per cent.).

Also in Svealand houses with iron roofs are more commonly infested than others (28 per cent.) and houses with tile roofs least attacked (22 per cent.) ; tar-paper is similar to iron, but houses with shingle are most commonly attacked (34·2 per cent.) (fig. 3).

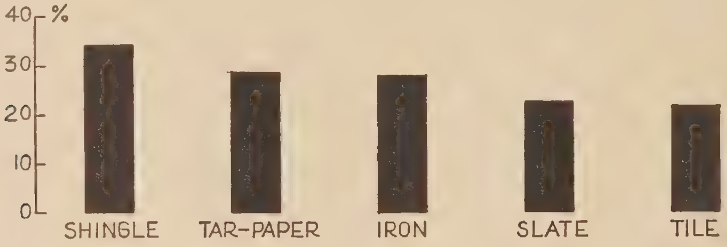

Fig. 3. Frequency of *Hylotrupes* in buildings with different roofing materials.

It is of great interest to compare these results with those obtained in Germany (Erhebungen über den Befall des deutschen Gebäudebestandes durch den Häuskäfer, 1936–1937) where an immense amount of data has been collected. The German houses with slate roofs show the highest percentage, next come straw roofs and roofs of smooth tiles, the houses with iron roofs being least attacked.

There is after all nothing remarkable in these differences, because it is obvious that it is not the roofing material in itself which is the deciding factor, but the way it reacts against the climatic factors to produce a temperature and degree of humidity of the air favourable or unfavourable to *Hylotrupes*. It is very likely that the roof-timber in Germany under iron roofs becomes too hot to suit the beetles, whereas in Sweden it becomes suitable.

Since *Hylotrupes bajulus* is the most important pest of buildings in Sweden it is of interest to know its geographical distribution. The relevant data are summarized in Table V. There are no records of the beetle in the county of Kopparberg, which is

TABLE V.

The Geographical Distribution and Frequency of Hylotrupes *in Svealand.*

County	Total	*Hylotrupes*	Percent. attacked, all buildings	Attacked houses	Percent. attacked, houses
Stockholm	467	68	14·6	243	27·9
Uppsala	225	41	18·2	123	33·3
Vastmanland	92	0	0	36	0
Örebro	230	10	4·3	70	14·2
Värmland	329	53	16·1	112	47·3
Kopparberg	118	0	0	33	0
Södermanland	216	6	2·8	57	10·5
Gotland	124	34	27·4	115	29·5

the most northern county, nor from Vestmanland. In order to ascertain whether this represents the northern limit of its geographical distribution it is, however, necessary to make special investigations. The only conclusion that can be safely drawn from the present material is that the beetle probably is rare in the northern part of Svealand.

In the first survey (*l.c.* fig. 3, p. 62) an attempt was made to investigate the influence of the age of the houses on the frequency of the attacks of *Hylotrupus bajulus* and *Anobium striatum* in Götaland. Altogether 637 reports (or 70·5 per cent.) contained information on this point. The exact ages of the houses were recorded only in 143 instances. The age was divided into 10 groups and the frequency of attacks plotted in the diagram. We notice that percentage of attack rises with the increasing age of the houses until 30 years, when it remains fairly constant. This must not be interpreted as indicating that the insects prefer old timber to new. Rather it expresses the fact that with every year the chances of infestation increases until 30 years, when it reaches its effective limits, so that no further increase occurs.

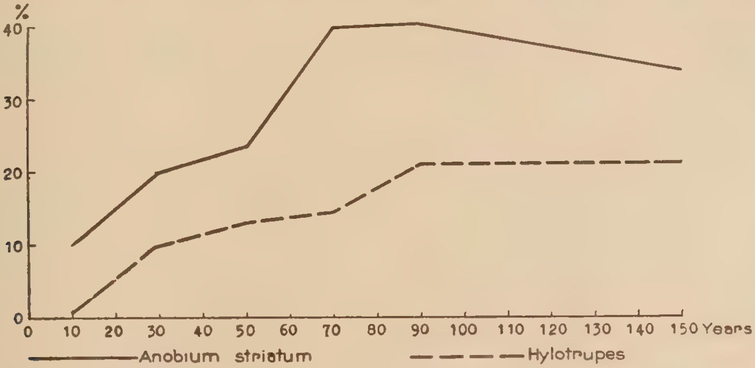

Fig. 4. Diagram illustrating the influence of the age of the buildings on the frequency of attacks by *Hylotrupes* and *Anobium striatum*.

The data from Svealand tally with those from Götaland (fig. 4). Also in this investigation *Anobium striatum* was more frequent than *Hylotrupes* and the percentage of attack rises with the increasing age of the houses until at 40–70 years age no further increase is found.

This investigation was supplemented by an investigation of 340 houses in Stockholm. Of these 195 (or 57·3 per cent.) were attacked. The age of the houses was possible to ascertain in 293 instances. The houses were divided in age-classes of 25 years and the degree of infestation was divided into 3 classes: I=a few timbers slightly infested, II=either slight infestation in most timbers or several timbers severely infested, III=most timbers severely infested.

Table VI summarizes this investigation. It is hardly necessary to point out that the results are very approximate, because an attack is the consequence of several factors which it is impossible to grasp by the statistical treatment of such incomplete material. For instance, the influence of the quality of the timber and risk of exposure to infestation from other houses are two important factors, the influence of which it was not possible to investigate.

Nevertheless the results agree with those already obtained. Thus no attack was recorded in houses not 25 years old; of houses 26–50 years old 31 per cent. were attacked, but no attack of degree III, which means that the attacks were in their initial stages; in houses 51–75 years old this class was 20 per cent.

The decrease of the attack in houses 101–125 years old is obviously due to the fact that this class contained only 17 houses.

TABLE VI.

The frequency of Hylotrupes *in Buildings of different Ages in Stockholm.*

1937–1912 1–25				1911–1887 26–50				1886–1862 51–75				1861–1837 76–100				1836–1812 101–125				1811–1787 126–150				1787– 151–				Age unknown			
—	I	II	III	—	I	II	III	—	I	II	III	—	I	II	III	—	I	II	III	—	I	II	III	—	I	II	III	—	I	II	III
	0	0	0		5	2	0		19	9	7		27	19	14		5	2	0		9	3	6		17	8	8		27	2	6
29		0		15		7		25		35		27		60		10		7		8		18		19		33		12		35	
Total : 29				Total : 22				Total : 60				Total : 87				Total : 17				Total : 26				Total : 52				Total : 47			
Mean percentage 0				Mean percentage 31·8				Mean percentage 58·3				Mean percentage 68·9				Mean percentage 41·2				Mean percentage 69·2				Mean percentage 63·4				Mean percentage 74·5			

IMMATURE NUTFALL OF COCONUTS IN THE SOLOMON ISLANDS.

By J. S. Phillips, M.A., B.Sc., Ph.D.

(Plate XIII.)

Acknowledgments.

The research work involved in this paper was financed by Messrs. Levers Pacific Plantations Pty., Ltd., of Sydney, and I wish to acknowledge the help and courtesy extended to me by so many members of their staff.

Previous work on Nutfall.

As early as 1911, W. W. Froggatt recorded[1] that a Gizo planter had informed him that the bug *Axiagastus cambelli* was causing immature nutfall on his plantation. Though Froggatt did not confirm this, he suggested that the bug might be worth watching.

In 1923, H. W. Simmonds, the Fiji Government Entomologist, visited the Solomon Islands and noticed[2] the " very variable but generally poor yields " of coconuts on the Guadalcanal Coast. He observed[3] that premature nutfall exists and that it may be due to many causes. Both *Tirathaba rufivena* and *Axiagastus cambelli* were mentioned by him as pests attacking coconut spadices in the Solomons.

Some five years later, J. D. Tothill and R. L. Paine arrived from Fiji to make a survey of coconut problems in the Solomon Islands. Though only nine weeks were spent in the Protectorate, much valuable work was accomplished. The investigators considered that *Axiagastus cambelli* was responsible for immature nutfall and stated that " nutfall occurs roughly in proportion to the number of bug punctures." The life-history of this insect was worked out and two egg-parasites were found to attack it.

Furthermore, the relations of the bug with two species of dominant and mutually antagonistic ants, *Oecophylla smaragdina* and *Iridomyrmex myrmecodiae*, were studied in some detail. The former was found to destroy the bug, and palms occupied by its colonies bore good crops of nuts in consequence. The trees occupied by the latter species were very often found to be barren, and it was noted that this ant does not destroy *Axiagastus*. Tothill recommended[4] that the beneficial ant be encouraged and that methods be found to increase its distribution. He also thought that further study should be made of the injurious bug, *Axiagastus*.

As a result of other recommendations, an Agricultural Committee was formed, consisting of members representing both the Government and the Coconut Planters, and R. A. J. Lever was given a five-years appointment as Government Entomologist.

After the publication of Tothill's Report[4] and before Lever arrived in the Protectorate, certain experiments were made by Levers Pacific Plantations on Guadalcanal and by the Malayta Co. on Malaita.

These experiments were important and their results were highly significant. Briefly, various methods of protecting young nuts were tested. *Inter alia*, gauze cages were placed round the unopened spadices of palms in the nutfall areas. A year later, it was found that these spadices were bearing crops of healthy, mature nuts, while the neighbouring, unprotected spadices were barren.

The planters concluded from this that nutfall was due to insect agency. Two insects—the bug *Axiagastus* and the ant *Iridomyrmex* were suspected, as both of them were found consistently on barren trees.

In July 1931, R. A. J. W. Lever arrived and began to study nutfall in the Protectorate. His earlier researches led him to believe that the damage was inflicted by *Axiagastus cambelli* and the moth *Tirathaba rufivena*, when there is too little rain or in poor soil[9]. A number of other causes, *e.g.*, lack of manuring and cultivation, shortage of sunshine accompanied by heavy rain, were postulated from time to time[5, 6, 7, 8]. Soil samples were taken and sent for analysis overseas.

In July 1933, H. T. Pagden arrived from Malaya to investigate nutfall in the Solomons, Levers Pacific Plantations having offered an annual subsidy for five years, on the condition that an experienced and qualified research officer was appointed to work specifically on the nutfall problem.

Pagden concluded that the problem was cultural not entomological, and reported[10] adversely on the prevailing cultural practices. Experiments with *Axiagastus*[11] seemed to indicate that this bug was *not* the cause of nutfall. For the next eighteen months much valuable work was done in listing coconut insects, but both entomologists adhered to the view that nutfall was primarily a physiological problem, intimately associated with soil conditions, rainfall and cultivation[12]. It was therefore decided to replace Pagden by a Plant Physiologist. The reports of soil samples, taken from nutfall areas and sent to oversea experts, were surprisingly favourable ; and samples from good and bad areas, which had been sent to London, showed " insufficient differences to account for the enormous differences in fertility." A noticeable feature of the " nutfall " trees was that the foliage appeared to be perfectly healthy, a point against the theory that nutfall was due to soil conditions.

The management of Levers Pacific Plantations were sceptical of this theory, in view of the plain evidence to the contrary supplied by the caging of spadices on their estates. Accordingly, in August 1934, they urged that further cage experiments be carried out, similar to those they had undertaken themselves in 1929 and 1930. As a result of this, the investigators put up 40 cages in December on Messrs. Levers' Guadalcanal estates.

In February 1935, Pagden left the Protectorate, and a month later, Lever revisited Guadalcanal to examine the forty cages. He found that 80 per cent. of the spadices therein bore nuts, whereas only 32 per cent. of the uncaged spadices did. From this evidence, he deduced that " nutfall was caused by an insect large enough to be unable to get inside the wire gauze cage ; " and, as *Axiagastus* had been shown to be non-causal, suspicion fell on the Coreid bug, *Amblypelta cocophaga*[13], which he had noticed to be the cause of shrivelling of button-nuts three or four years earlier[9]. Further cage experiments were made in the same area and were found in September to give positive results, the cages containing bugs showing 90 per cent. nutfall, the controls only 71 per cent.[14].

In the meanwhile, Messrs. Levers Pacific Plantations had decided to engage an entomologist on their own account. An appointment was made in July 1935 and the entomologist arrived in the Solomons in October.

Conspectus of the Nutfall Problem.

The Non-Bearing Areas.

The non-bearing areas are of two types. The first is represented by certain areas of trees with unhealthy-looking foliage. These trees have never produced a crop or at best only a very poor one. This type of non-bearing is, no doubt, due to the fact that the ground is unsuitable for coconut palms.

The second or *nutfall* type contains healthy-looking trees with glossy foliage. Their freshly-burst spadices show the normal flowering-branch with an abundance of nuts. Yet these nuts never—or rarely—mature, but fall to the ground when they are only one or two inches in diameter.

The Nutfall Areas.—Distribution.

In general, immature nutfall occurs, irregularly distributed, on all the large islands of the South-East Solomons, viz. : San Cristoval, Guadalcanal, Malaita and the New Georgia Group ; but not on many of the small ones, notably the Russell Isles, the Three Sisters, Nggela and Savo. It has not been found in the North-West Solomons—Choiseul, the Manning Straits Islands or the Shortlands Islands, nor in the neighbouring islands of Bougainville and Buka, which belong politically to the Mandated Territory of New Guinea. With regard to Ysabel, the position is uncertain, as reports disagree and no proper investigation has been made there.

Wherever this type of nutfall has been found, the bug *Amblypelta cocophaga* has been shown to be present too : and, conversely, *Amblypelta* has not been located in those areas which are free from immature nutfall of this kind.

There are about 60,000 acres of coconut plantations in the Solomons. Very roughly a third of the planted area is on " safe " islands ; in another third, nutfall is already rampant ; while the remainder consists of estates into which nutfall is spreading or may shortly spread.

Yields in Nutfall and Non-nutfall Areas.

Though returns of copra yields are given in the Government's annual reports, statistics for them have not been collected for about ten years, and the returns therefore show the position about 1926. It is as follows :—

Total acreage.	*Copra output.*	*Yield per acre.*
62,309	19,925 tons.	6·4 cwts.

The acreage planted since then has been small, and certain planted areas have been abandoned. In some islands, *e.g.*, the Russell Group, the yield per acre has increased ; in others, *e.g.*, Guadalcanal and Malaita, it has fallen off.

The yield of plantations varies greatly. Below will be found some statistics from certain nutfall and non-nutfall estates during 1938. The average annual rainfall is also given, as previous investigators have maintained that excessive or scanty rainfall is an important contributory factor to nutfall here, a statement which the facts do not support ; moreover, productive and barren areas are often found in juxtaposition, where the variation in rainfall must be inappreciable.

Nutfall Estates on Guadalcanal.

Estate	Acreage	Yield (tons)	Cwts. per acre	Average annual rainfall
A	2,419	363	3·0	75·6
B	878	157	3·6	71·7
C	654	25	0·8	80·6
D	946	360	7·6	102·4
E	137	53	7·2	101·6
F	946	165	3·5	167·2
Total ...	5,980	1,123	3·8	
Nutfall Estates in New Georgia Region.				
G	659	183	5·6	174·0
H	1,153	127	2·2	129·2
I	1,563	402	5·1	117·8
J	783	254	6·5	112·5
K	437	126	5·9	128·5
Total ...	4,595	1,092	4·8	
Nutfall Estates on Malaita.				
L, M & N	2,244	487½	4·5	—

As a comparison, here are the corresponding details of some estates where nutfall is *not* present.

Non-Nutfall Estates in the Russell Islands.

Estate	Acreage	Yield (tons)	Cwts. per acre	Average annual rainfall
O	2,056	1,332	13·0	132·4
P	770	328	8·5	134·3
Q	938	481	10·3	125·0
R	800	463	11·6	133·3
S	2,048	1,265	12·4	111·1
T	811	497	12·3	109·7
U	1,027	518	10·1	127·6
V, X & W	3,319	2,228	13·4	—
Total ...	11,769	7,112	12·1	

Non-Nutfall Estate in Eastern Solomons.

Z	962	491	12·1	192·2

The above statistics show that the average nutfall estate now produces about a third of the crop yielded by an unattacked plantation. Furthermore, all the attacked estates still contain some non-nutfall areas, though these areas are diminishing year by year. Their annual yield, therefore, will become progressively less.

Most of these estates belong to Messrs. Levers Pacific Plantations, and their nutfall areas comprise about three-fifths of the property owned by this company and produce only about two-fifths of their copra output.

The following figures show what has happened on two typical nutfall estates during the last ten years. For comparison, two estates in non-nutfall areas are also given. As before, the estates are lettered and not named, because the production figures of private companies are confidential data.

Estate	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
B	371	304	281	346	220	198	194	189	178	157
	8·5	6·9	6·4	5·6	5·0	4·5	4·4	4·3	4·0	3·6
A	488	277	225	189	121	130	119	104	65	65
	7·1	4·0	3·3	2·8	1·8	1·9	1·8	1·5	0·9	0·9
T	451	461	448	427	435	439	446	431	503	497
	11·1	11·3	11·1	10·5	10·7	10·8	11·0	10·6	12·3	12·3
R	523	567	571	610	545	555	556	535	500	463
	13·1	14·2	14·3	15·3	13·6	13·9	13·9	13·8	12·5	11·6

NOTE.—The upper figures represent the annual output in tons, the lower figures the yield in cwts. per acre.

In ten years the annual yield on Estate A has declined from 7·1 to 0·9 cwts. per acre; that on B from 8·5 to 3·6 cwts. On the other hand, the yields in the non-nutfall estates T and R have oscillated between 11·1 and 12·3 and between 13·1 and 11·6 cwts., respectively.

Copra-cutting usually occurs at about six-weekly intervals, so that the annual yield may comprise either 8 or 9 of these cycles, depending on how they fit in with the calendar year. There is also a certain amount of " normal " fluctuation in the yield of any particular block, due to environmental conditions such as rainfall. Because of these factors, an annual variation up to say 20 per cent. in production of an estate, from one year to the next, may be without special significance ; but a drop or rise of this nature would be likely to be balanced by an equivalent rise or drop in the following year. A continued drop, as instanced by the first two estates in the above table, obviously cannot be accounted for in this way.

Crop returns show that nutfall had been in progress some years before its presence was suspected. Below (p. 300) are tabulated the crop returns for a typical nutfall estate on Guadalcanal. Instead of a gradual increase as the younger crops matured, and small fluctuations in the more mature crops, they show irregular increases and decreases, often very pronounced.

Attempts to correlate these yields with the rainfall of either the previous year or the one before it (which might be expected to influence the crop) do not show that there is any connection between rainfall and yield (fig. 1).

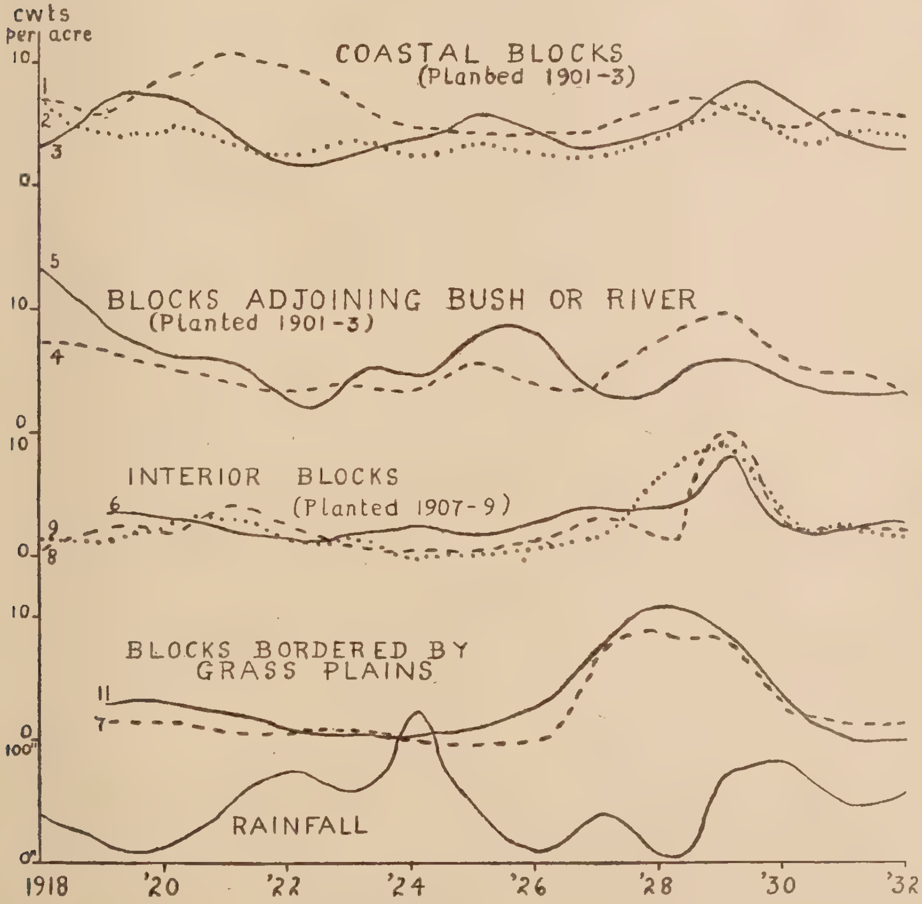

Fig. 1. Annual copra yield from blocks of a " nutfall " estate.

Estate A.

Yield of various blocks in cwts. of dry copra per acre.

Year	Crop tons	Block ...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average crop per acre
		Acres ...	230	67	108	85	19	39	149	47	114	175	26	98	76	100	17	31	
		Planted	1901–3	1901–3	1901–3	1901–3	1901–3	1907	1908	1909	1909	1909	1912	1912	1913	1915	1916	1916	
1918	244		7·02	3·71	6·71	7·08	13·34	3·01	3·01	1·12	1·74	1·05	—	4·67	—	—	—	—	4·22
1919	235		5·89	6·95	4·39	6·71	9·05	3·97	1·60	2·86	1·63	2·06	3·46	5·11	—	—	—	—	3·81
1920	273		9·32	7·55	4·87	5·23	6·47	3·36	1·33	2·51	2·95	3·48	3·34	2·67	0·40	—	—	—	4·40
1921	261		10·08	4·37	3·59	4·06	6·19	2·06	0·52	4·61	3·50	3·24	2·96	2·82	0·73	—	—	—	4·23
1922	198		9·25	1·82	2·39	3·25	2·59	1·38	0·30	2·66	1·23	2·02	1·07	3·39	0·23	0·30	—	—	2·97
1923	197		6·94	2·77	3·53	3·71	5·26	1·66	0·42	1·34	1·81	2·03	0·61	3·82	0·37	1·84	—	—	2·95
1924	135		4·76	3·61	2·59	3·07	4·63	2·21	0·46	0·53	0·31	0·58	0·58	2·75	0·30	1·09	—	—	2·03
1925	165		4·12	5·56	3·31	5·64	8·42	1·44	0·88	0·51	0·11	0·40	0·31	5·06	0·04	1·71	—	—	2·47
1926	180		4·13	3·75	2·80	3·24	8·10	2·80	2·15	1·30	0·84	0·59	0·11	7·89	0·42	1·65	—	—	2·70
1927	260		4·47	3·65	2·71	4·21	3·21	3·74	8·07	3·66	2·12	1·18	8·53	6·33	3·05	1·79	0·94	—	3·85
1928	398		6·17	4·75	4·28	7·66	4·21	3·69	8·87	1·45	7·14	6·00	11·50	4·21	7·48	1·65	4·53	3·64	5·77
1929	493		6·28	8·45	6·95	9·11	6·78	8·52	8·32	10·72	9·61	6·93	9·27	4·20	6·27	4·35	3·83	3·86	7·06
1930	278		4·67	6·45	3·19	5·34	4·31	2·01	2·89	2·28	2·67	4·86	3·60	2·90	4·76	3·70	3·00	6·97	4·00
1931	225		5·78	4·27	4·23	4·94	3·21	2·49	1·45	2·57	2·30	2·88	0·35	2·05	1·32	1·87	1·76	7·30	3·26
1932	188		5·11	3·72	4·09	2·89	3·98	1·87	1·23	3·07	1·94	2·62	0·63	1·99	0·77	0·75	0·70	4·65	2·73
1933	121		4·38	2·91	1·36	2·64	1·49	2·40	0·44	1·01	0·98	2·20	0·52	0·12	1·99	—	—	—	1·76
1934	130		4·38	2·27	1·96	1·56	4·13	2·21	0·44	1·28	2·18	2·72	—	0·54	—	—	—	1·20	1·89

The sixteen blocks of this estate are variously bounded by sea-coast, bush, river and grass plain, the river borders usually having an intervening fringe of bush. It might be thought that by classifying the area into blocks bordering grass plains, coast and river-and-bush, it would be easy to show the place of origin and spread of nutfall over the period from the annual records of copra yields. But, actually, one cannot do so, because the blocks have been planted at various times and in various parts of the estate between the years 1901 and 1916, and this complicates the issue so much that a block by block comparison is not possible.

Nevertheless, if we take some of the older stands (planted 1901–3), it is evident that while coastal blocks (such as 1, 2 and 3) show a fairly even output, bush and riverside blocks (4 and 5) of the same age show a downward tendency with irregular fluctuations. In the case of the latter blocks, a sharp downward trend is apparent as early as 1918, which suggests that nutfall was in evidence there at that date.

On the whole, the interior blocks (6, 8 and 9) and those bordered by grass plains (7 and 11)—all planted in 1907–9—do not show a pronounced drop in production till about ten years later, and this suggests that the cause of nutfall came in from the bush and spread very slowly, a theory substantiated by observations from estates in other parts of the Group.

Amblypelta cocophaga, the suspected cause of nutfall, is a bush insect. It feeds on several jungle trees and shrubs, found both in the bush and as plantation undergrowth.

Though a few native groves existed previously along the foreshore, no European plantations were made here until 1901. Immature nutfall, however, did not become a serious problem until about 20 years later, though several plantation blocks adjoin the bush where *Amblypelta* occurs without any intervening barrier. If this bug is really the cause of nutfall, why did such a long period elapse before it invaded the plantations and its depredations became apparent ?

Ants and Nutfall.

In the dense, unexplored bush of the Solomon Islands Mann[15] found over 140 species of ants in a few months. A similar search of coconut plantations would reveal only four species—save for a few small colonies of indigenous ants. These four species are as follows :—

The two tropicopolitan invaders—*Pheidole oceanica* and *Anoplolepis longipes*. These ants seem to have been introduced in comparatively recent times by man ; they are found near settlements and in the coastal areas. *Iridomyrmex myrmecodiae* may be a native or perhaps an earlier invader. By reason of its symbiotic relations with epiphytes, it has spread widely into the coastal bush areas—notably on Malaita —but so far it does not seem to have reached the Russell Isles or New Georgia. The first two species have barely penetrated the bush at all, and where they have done so, they are by no means dominant ; but in the areas of coconut plantations they occupy no other ant species are allowed to co-exist, except in insignificant numbers. The fourth species, *Oecophylla smaragdina* var. *nitida*, the yellow tree-ant, is a true native. It is one of the commonest bush-ants at lower elevations. Its leaf-nests, bound together with mucilaginous threads exuded by its larvae, are found in a variety of trees and the innumerable jungle creepers are its favourite pathways. In the Russell Group it still occupies large areas in the plantations, but elsewhere it is being slowly driven out by the other three species, in particular by *Pheidole*. It seems likely—though we have no detailed information on this point—that *Oecophylla* was originally the dominant ant on the Guadalcanal nutfall estates, and that *Pheidole* and, to a lesser extent, the other species have gradually encroached on its territory, till by now *Oecophylla* has practically disappeared from these plantations.

This matter of the ant population is intimately linked with the nutfall problem. Planters, managers and investigators alike have noticed that where *Oecophylla* is present the trees almost invariably bear well, whereas in the nutfall areas the trees are almost always occupied by *Pheidole* or *Iridomyrmex*. *Anoplolepis* areas are usually good-bearing areas, and on the whole this is a beneficial ant.

This linkage of ant species with nutfall gave rise to the widely-held opinion that the " bad " species were directly responsible for nutfall. The real reason, however, is that whereas *Oecophylla* and *Anoplolepis* destroy or drive away any *Amblypelta* they may find on the spadices, *Pheidole* and *Iridomyrmex*,* though they will also destroy the bug if they can catch it, are much smaller and move much more slowly than the other two species, so that the bugs are usually able to get away from them.

The presence of *Oecophylla*† and probably of *Anoplolepis* colonies on palms therefore protects them against immature nutfall caused by bug injury, whereas the presence of colonies of the other two species does not do so. It seems likely that the Guadalcanal plantations were protected in their earlier years by the presence of *Oecophylla*, and that as this species was driven out by *Pheidole*, *Amblypelta* with its concomitant nutfall advanced. I have myself seen this happening in areas on Guadalcanal, where the progressive replacement of *Oecophylla* by *Pheidole* was very marked during the three years of my work there.

Nevertheless, although in most of the planted areas *Oecophylla* is expelled by the other species, there are a few places where it has held its ground, and even one or two where it has been observed to advance into *Pheidole*-held territory and reoccupy it. It therefore seems possible that, if we could only ascertain the ecological circumstances which favour the establishment and maintenance of *Oecophylla* colonies, it might be feasible to reproduce them in the plantations.

In the past, considerable effort and money have been expended by a company on Malaita and by Mr. Markham, a private planter of New Georgia, to establish *Oecophylla* in areas occupied by other ants. The methods used included the transference of leaf-nests from the bush, the connecting of palms with rope and creeper runways and attempts to poison the harmful species. Unfortunately these attempts all failed. Experiments on these and other lines made by us met with equal ill-success.

The Initial Cage Experiments.

The result of the cage experiment made at the end of 1934 had shown the long-held soil theory of nutfall to be untenable and brought suspicion on the Coreid, *Amblypelta cocophaga*.

To check this, in July 1935 Lever caged 28 new coconut spadices on Guadalcanal and Tulagi ; half of these contained up to seven *Amblypelta* nymphs and adults each, while the others were left empty as controls.

I had just arrived in the Protectorate, so the results of this experiment were noted during a joint visit to Guadalcanal of Lever and myself in November 1935. They showed[17] that whereas in the control cages only 70 per cent. of the nuts had fallen (approximately the figure for " normal " or physiological nutfall) the cages where *Amblypelta* had been enclosed averaged 90 per cent. nutfall.

Climbers were sent up the palms daily during this visit. In general, the boys found bugs on palms in the nutfall areas, though never more than 3 or 4 bugs per tree and usually less, whereas none was found on palms in the bearing areas.

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* Previous workers believed that the " harmful " ant species tolerated *Amblypelta* and *Axiagastus*, but tests in confined spaces have shown that this is not the case. It is merely that they are unable to catch them in the palm-crowns, where the bugs are able to elude their less nimble foes.

† Sampson considers this species " as being harmful in preventing the female flowers from being fertilised " [16]. This is not the case in the Solomons, possibly because the mealybugs it fosters in Madras may not occur here.

The tree search and the cage experiment tended to support the theory that *Amblypelta* was the cause of nutfall, but I was not yet convinced—for the following reasons :—

(1) The cage experiment had been made on too small a scale to warrant drawing any conclusions.

(2) Too many details had been left to native climbers, who appeared to be unreliable.

(3) Damages to cages and insects were all too likely to occur and were, in fact, noticed in certain cases ; these would affect the results.

(4) The fact that nutfall was induced in nutfall areas was not a very satisfactory test. To induce nutfall in *non-nutfall* areas would be far more convincing.

Accordingly I decided to make further cage experiments and to conduct them simultaneously in nutfall and in non-nutfall areas, the first on estates in the Guadalcanal nutfall area and the second on Gavutu-Tananbogo, a small islet on which both nutfall and the bug *Amblypelta* were unknown.

Nutfall Induction Tests with Amblypelta.

An experiment was made in Nov.–Dec. 1935 in a non-nutfall area on Guadalcanal. Six *Amblypelta* (nymphs and adults) were encaged* for 6 weeks with a newly-opened coconut-spadix, 37 cages (21 with bugs and 16 without bugs) being used in the tests. The results showed that whereas only about 60 per cent. of the nuts fell in the " control " cages, 90 per cent. fell when bugs were enclosed with the spadices. This confirmed Lever's results and materially strengthened the case against *Amblypelta*.

A further test was made on the islet of Tananbogo (a non-nutfall area) during a 6-weekly period in Jan.–March 1936, but a severe storm occurred a week or two after the cages had been put up and damaged most of them, killing the bugs or allowing them to escape from the cages.

In the four bug cages which remained intact, the nutfall was again 90 per cent., but in the broken cages it was 63 per cent., *i.e.* approximately the figure for normal nutfall. This suggested that the bugs did no damage to the nuts during the first two weeks of the experiment and that the danger-period is from the end of the second to the end of about the sixth week. (It was thought at the time that nuts over six weeks old were not liable to immature nutfall, because occasional trees with half-grown nuts were seen in the nutfall areas.) This idea of a particular danger-period in the life of the spadix, during which the nuts were liable to injury, led to experiments in nut-protection, which are described later. The concept, however, was a mistaken one, as I soon found that nuts could be induced to fall both before and after the suspected danger-period. The real reason that the nuts were not attacked during the first two weeks was probably because the bugs were then feeding on the male flowers of the spadix, which mature and fall off during the first three weeks after the spadix opens. Immediately after this has taken place, the female parts of the spadix (*i.e.* the young nuts) flower ; but prior to this, it seems likely that the male flowers are more palatable.

A further induced nutfall test was made in March–April 1936 on Tananbogo, using this time only nymphs and reducing the duration of the test from 6 weeks to 3. The age of the spadices ranged from 1 to 4½ weeks. The results showed an average of 96 per cent. nutfall. The youngest spadix was inspected daily, and most of the nuts punctured on it fell before the female flowers opened, showing that the inference drawn from the previous experiment (that the nuts were safe during the first two weeks) was incorrect and that nuts were not immune during the period when male flowers remained on the spadix. Furthermore, as the oldest spadix was equally affected, it suggested that *Amblypelta* might be able to cause nutfall in older nuts, too.

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* The cages used were made of a timber frame and wire-mesh panels in the shape of a truncated cone. They were 3′ 6″ long and 2′ 0″ square at the base. At the apex was an open canvas throat, which was fastened with string after the cage had been placed over the selected spadix. A small door in one of the sides allowed the insertion of bugs. The cages were hauled up to the palm crowns by means of a rope.

This possibility was of great importance, for though it might be economically feasible to protect the youngest spadices on each tree by mechanical or chemical means, if such methods had to be applied to the other spadices as well, the cost would be prohibitive. The next step was obviously to probe this matter by experimenting with older spadices.

In April and May 1936, tests were made on older spadices, varying from 4 to 14 weeks after they had burst. They were set up as follows : 22 cages on Tananbogo and 24 on Guadalcanal.

The results varied considerably and were complicated by damage caused by wind and rain. Over 50 per cent. nutfall was caused on spadices between 3 and 4 months old, which have a normal nutfall of less than 20 per cent., according to the few control cages we were able to use. Later observations suggest that this latter figure is unusually high and that there is in fact very little normal nutfall after the twelfth week. The percentages of induced nutfall in the younger spadices was very much higher than in the oldest ones. Nuts 8 to 10 weeks old showed an induced nutfall rate of 62–87 per cent., while the 4 to 6 weeks old spadices ranged from 81–100 per cent. nutfall. The results seemed to indicate that though the percentage of induced nutfall decreases as the age of the nut increases, at least five spadices on each tree would have to be protected in any defensive scheme of bug control. Whether *Amblypelta* will cause nutfall in spadices over 4 months old is not known, as no tests were made, for it was already clear that to avert nutfall by protecting the spadices could never be economically practicable.

Minimum Number of Bugs necessary to cause Nutfall.

The nutfall induction tests, taken in conjunction with other evidence mentioned elsewhere in this paper, proved conclusively that *Amblypelta* was the main cause of immature nutfall in the South-East Solomons and the New Georgia Region. The fact that though only six bugs were used in the cage tests almost complete nutfall was induced, coupled with the fact that only very few bugs per tree could be found by our climbers in the barren nutfall areas, indicated that any form of control would have to be almost complete before nutfall could be checked. But how complete ?

It seemed advisable to make a test to find out the minimum number of bugs necessary to cause the average 90 per cent. nutfall of the nutfall areas. Accordingly a six weeks test was made on Gavutu during May and June 1936. Twelve cages were used, some of which contained 3 bugs, some 2 and some only 1. The results were as follows :—

No. of bugs per cage.		*Percentage Nutfall.*
1	... ...	94 per cent.
2	... ...	78 ,, ,,*
3	... ...	100 ,, ,,

This shows that even a single bug may be sufficient to denucify a spadix, and thus very drastic control of *Amblypelta* would be necessary before an area would come into bearing again.

It may perhaps be argued that, in the field, bugs are not confined for a period of weeks on any particular spadix and so the artificial conditions of the experiment may have produced a misleading result. A more reliable indicator was furnished by the population counts made in the Guadalcanal nutfall area given below.

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* Three of the cages were damaged during the course of the experiment and bugs escaped. This probably accounts for the lower figure in this case.

The object of these counts was to get some idea as to the number of bugs present in nutfall areas and to see whether there was any seasonal fluctuation. Such counts would also be a guide as to the number of bugs per tree necessary to cause nutfall, though even with experienced boys the *observed* number would always be less than the *actual* number present.

Three sample plots, each containing 21 palms, were chosen and marked, and boys made weekly counts of the numbers of nymphs and adults they found on each tree. A point brought out was that when the bug population increased, there was a greater number of small-sized nutfalls ; conversely, when there were fewer bugs, the proportion of larger-sized nutfalls increased. The counts show the very small number of *observed* bugs per tree necessary to cause complete nutfall—for this area was entirely barren and remained so throughout the period of the experiment.

The following table shows the number of *observed* bugs per tree recorded in the sample plots : they were made over three-weekly periods in 1937 and six-weekly periods in 1938–39.

Period ending	Observed no. of bugs per tree	Period ending	Observed no. of bugs per tree
June 9, 1937 ...	1·02	Nov. 1, 1938 ...	0·67*
June 30 ,, ...	1·10	Dec. 7 ,, ...	1·19
July 21 ,, ...	1·31	Jan. 20, 1939 ...	1·10
Aug. 11 ,, ...	1·42	Mar. 3 ,, ...	1·49
Sept. 1 ,, ...	1·75	May 25 ,, ...	No record
Sept. 22 ,, ...	1·92	July 10 ,, ...	0·98
Oct. 13 ,, ...	1·80	Aug. 1 ,, ...	0·85
Nov. 29 ,, ...	1·36		

* Low count may be due to boys being new to the job.

Further light on the distribution and movements of the *Amblypelta* population in a nutfall area was obtained from the following test.

Handpicking Experiment.

A plot of 15 palms was selected in the Guadalcanal nutfall area, and climbers were sent up daily to collect all *Amblypelta* bugs on the spadices ; these were recorded and classified according to their stages.

The experiment was initiated on 24th May 1937 and concluded on 30th November 1937. During this period, 766 nymphs and 1,277 adults were caught. The average number of bugs per tree per day, found throughout the six months, was 0·6. Except for the first few days, a note was made of the numbers of the different nymphal stadia, which were as follows :—

Stadium I	6	Stadium IV	72
Stadium II	486	Stadium V	45
Stadium III	158	Adults	1,253

The small number of stadium I nymphs caught was very puzzling, for it was not till later that it was discovered that the central leaf-spike of the palm was favoured as an oviposition site, and that many of the stadium I nymphs were also found there.

The fact that in spite of the daily handpicking an average of 0·6 bugs per palm was found showed that the *Amblypelta* population—especially the adult bug—is constantly moving within the plantations. Notwithstanding six months of daily bug removals, little improvement was noticed in the crop borne during the course of the experiment.

The above two experiments and also the nutfall observation test on page 303 were carried out by my assistants Messrs. Dick and Love during my absence in the East Indies. Mr. Cottrell Dormer supervised the arrangement of the work.

Corroborative Negative Evidence against Amblypelta.

During a number of visits to the Russell Group, where nutfall has never been observed, opportunities were provided for searches for *Amblypelta*, both on the estates and in the surrounding bush. No trace of the bug was found. The fact that there is no immature nutfall (apart from " normal " nutfall) in the Russell Group is an additional piece of evidence, even though of a negative character, against *Amblypelta*. Moreover, *Axiagastus*, the Pentatomid bug believed by Tothill to be the cause of immature nutfall, was common here, though the plantations are among the best-bearing ones in the Solomons. A search in the Shortlands Group, another non-nutfall area, gave similar results.

The Coreid Bug, Amblypelta Cocophaga, China (figs. 2, 3 and 4).

This insect was first noticed by Lever[5], who mentioned in his annual report for 1931–2 that " an undetermined species of *Dasynus* does considerable injury to the young nuts before the stigma protrudes and the male flowers fall off." Later he described[18] the bug in all its stages. In 1934, China[19] published a much fuller description of the adult, which he re-classified and named. It was not until 1935 that it was recognised to be responsible for immature nutfall.

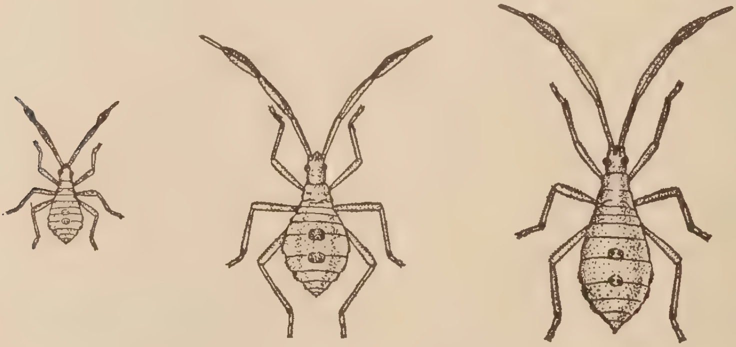

Fig. 2. *Amblypelta cocophaga*, China ; nymphs, stadia I, II and III (×3).

The main reason why the cause of nutfall remained so long undiscovered was that the damage takes place in the crown of the palm, where observation is difficult. Nearly all the searches were made by native climbers, and on the rare occasions when the crown was inspected by a white investigator, the act of climbing had so shaken the tree that any adult bugs would probably have flown away before he reached the crown.

Realising this, I had platforms built in the crowns of half a dozen palms at Gavutu, so that the bugs could be watched from day to day without disturbing them, and their behaviour and the reactions of the attacked nuts studied.

When *Amblypelta* is caged on a spadix, it acts as follows :—During the first two weeks the bug usually attacks the male flowers (Plate XIII, fig. 1) and the stems to

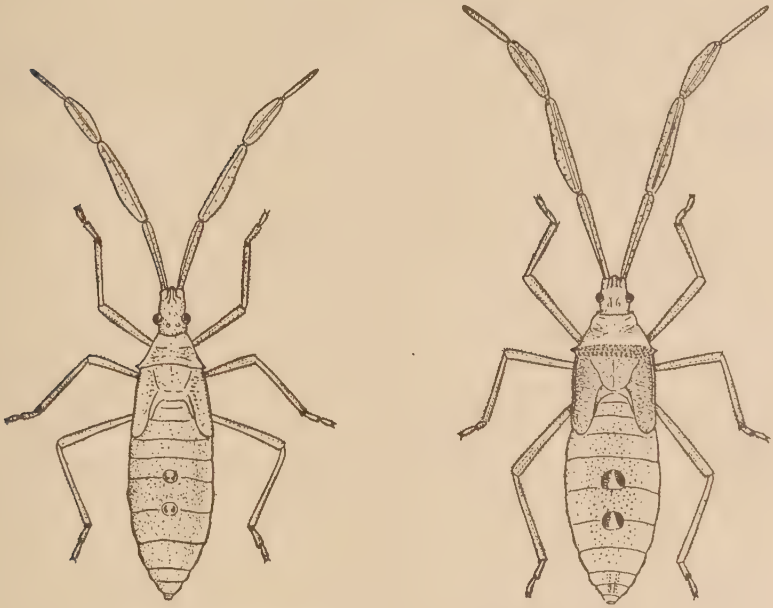

Fig. 3. *Amblypelta cocophaga*, China ; nymphs, stadia IV and V (× 3).

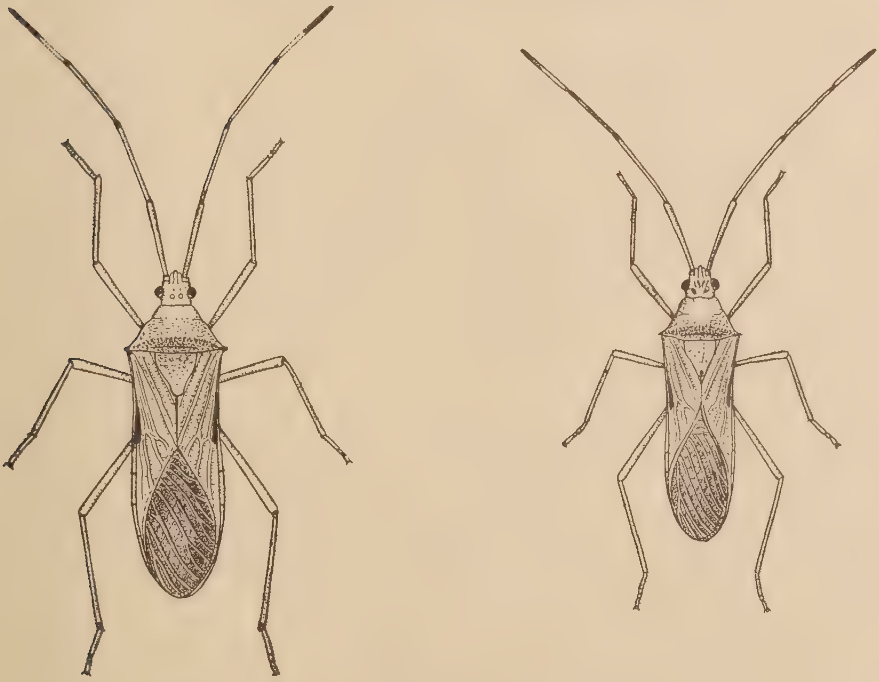

Fig. 4. *Amblypelta cocophaga*, China ; adults, ♀ ♂ (× 3).

which they are attached. But as soon as these flowers drop, and often before, the bugs settle on the young nuts, their favourite position being at the base ; possibly the composition of the sap is more palatable here, and certainly the integument is softer and juicier. It is these basal punctures which appear to cause nutfall, for they produce the typical tissue shrinkages and rot patches, which every *Amblypelta*-made nutfall shows.

The bugs also attack the flower-stalks and the main stem of the spadix, especially at the junctions of stalk and stem. Brown blotches result from these punctures, but they appear to do no other harm.

Life-cycle of the Bug in the Laboratory.

To rear *Amblypelta* in the laboratory, freshly-cut coconut spadices were used and these proved fairly satisfactory. They were placed with the bugs in cylindrical cages of brass and wire-gauze ; fresh spadices were introduced every three days and the old ones were removed.

In spite of this, there was considerable mortality among the bugs ; and this wastage continued, even when the bugs were reared on living *Ficus* and bean plants, as they were during the later periods of research.

The durations of the different stadia were found to be as follows (test period, February to June, 1936) :—

Egg stage		6–7 days (8)
Nymph : Stadium	I	3–4 ,, (4)
,,	II	7 ,, (7)
,,	III	6 ,, (6)
,,	IV	7 ,, (7)
,,	V	7–8 ,, (9)
Oviposition to emergence of adult		37–38 days (41)

The figures in brackets are the corresponding periods noted by Lever in his tests. Dick made further tests in August to October 1937 and obtained a total period of 36–37 days.

The bugs do not appear to mate till 9–14 days after emergence ; copulation occurs several times during adult life. Oviposition starts about a week after the first coupling. The highest numbers of eggs recorded in our tests were 163, 152 and 150, and these eggs were laid during a period of about two months in each case. The females used were found to start oviposition in 15–19 days after they had moulted to the adult stage. An adult life of about 12 to 13 weeks appears to be the maximum for this bug, the life of the male being usually rather shorter.

Life-history in the Plantations.

As temperatures and food are practically identical with those in the laboratory, there is no reason to believe that the length of the life-cycle differs appreciably.

Adults and nymphs (except stadium I) are found on the coconut spadices and on a variety of undergrowth plants, notably *Ficus leucantotoma* and *Macaranga tanarius*. The proportion of nymphs to adults and also that of the different stadia found are approximately what one might expect from the duration of the stadia, though on the youngest spadices the bugs are mostly adults. This is doubtless because their wings enable them to migrate more easily.

Stadium I nymphs, which though small are rather conspicuous on account of the white area on their tarsi, are found far less frequently on spadices than are the other stadia, even when allowance is made for the fact that the duration of this stadium is only half that of the others. Nymphs of this age can be reared on water alone and will even sometimes survive and moult without any food at all. Nevertheless, if placed on a new spadix, they will feed.

Many vain searches were made for the eggs, and very occasionally one or two were found on the young nut or on some other part of the spadix. Doubtless some are laid on the numerous male flowers which fall during the first two or three weeks of the life of the spadix. (In the laboratory this was often the case.) It was not until early in 1938 that Mr. Love found that eggs were frequently laid on the leaflets of the central spike, *i.e.* the new, unopened leaf. He also found nymphs on this part of the palm, and it seems likely that they migrate from here to the spadices. This seems to indicate that any form of control that only takes the spadices into account is doomed to failure.

The life-history of a typical *Amblypelta* bug would thus be as follows :—The egg and first nymphal stages are spent on the central leaf-spike (10 days) ; then follows a period of wandering through the crown until the nymph reaches a young spadix ; there it may remain feeding for the rest of its nymphal life (approximately a month) ; finally it will emerge as an adult and fly away to a new spadix on the same or on an adjacent tree, where it will feed, mate and later oviposit, often, though not always, on a convenient central spike ; after this, it will die. (The adult stage may be estimated at about six to twelve weeks.)

But it must be remembered that many bugs in the plantation are not found on the palms but on *Ficus leucantotoma* and other undergrowth shrubs ; and this is true of all stages of the bug, including the eggs. Thus, even if it were possible to spray, dust, trap or starve every bug on every palm in every block of a plantation—as it most assuredly is not—many bugs would still be left in the plantation to reinfest the palms.

Distribution.

A. cocophaga has only been found in the British Solomon Islands, where it occurs on most of the larger and some of the smaller islands. The bug has been observed on Guadalcanal, Malaita, Santa Anna, New Georgia, Kolombangara, Rendova, Tetipari, Vella Lavella and Ganonga. Immature nutfall is in every case concurrent. This Coreid is not present in the Russell Group, the Three Sisters Is., Shortlands Is. and the Manning Straits Is. ; nor has it been found on Choiseul.

Other species of *Amblypelta* occur on Ysabel and Guadalcanal in the Solomons, in New Britain, New Caledonia, Queensland and New South Wales ; but they are not coconut pests. More species of *Amblypelta* have been recorded from the Dutch East Indies—from the Kei Islands, the Timor Group and Lombok ; but only from the eastern side of the Wallace Line, which would appear to be the western limit of distribution of this genus. West of the Wallace Line a number of species of the closely-related genus *Dasynus* are found, and some of these also occur to the east of it.

Host-plants.

The commonest host-plants of *A. cocophaga* are the coconut palm, *Ficus leucantotoma* and two other unidentified *Ficus* spp., and *Macaranga tanarius.* Besides these, a number of other bush shrubs belonging to the families Euphorbiaceae, Leguminosae, Malvaceae, Meliaceae and Vitaceae act as hosts ; of these, so far, only the following have been determined : *Homalanthus populifolius*, *Leea sambucina*, and species of *Glochidion*, *Canarium* and *Dysoxylum*. Usually the leaves and young stems are attacked, but in the case of *Ficus*, the fruit also suffers.

The bug has also been found feeding on the following introduced plants : *Jatropha curcas* (leaves), *Codiaeum variegatum* (leaves), *Poinsettia pulcherrima* (fruit and leaves), *Poinciana regia* (pod), *Triumfetta Bartrami*, beans, cow-peas, melons, oranges, granadillas, red chillies, sugar-cane, manioc and muscatels.

In September 1938, bugs were also found at Baunani (Malaita) feeding on stems and shoots of papaya, causing lesions and rosetting of crowns, similar to those I have found in North Queensland in the case of punctures by *Amblypelta lutescens*. Here, also, the bug was found attacking the stem and new leaves of kapok, causing twisting, shrivelling and eventually defoliation.

Enemies of Amblypelta.

Amblypelta appears to have few enemies of importance. Of the predatory insects found in the plantations, a Reduviid, *Euagoras dorycus*, was found to attack both nymphs and adults, and it was at first thought that if its numbers in the plantations could be increased it might become an important controlling factor. But experiments in large cages showed that the predatory propensities of this bug are extremely variable. Sometimes half a dozen *Amblypelta* bugs would be killed and sucked dry within forty-eight hours ; on other occasions most of the experimental batch would be left unharmed for over a week. Moreover, the life-cycle of this predator from egg to adult was worked out and found to be over two months, which is 50 per cent. longer than that of *Amblypelta*. The few females tested only laid about thirty eggs each. In view of these facts, it seems likely that this Reduviid does destroy a few bugs on the plantations but not sufficient to make any appreciable difference.

Ants are far and away the most important predators. As was noted earlier, *Oecophylla* gives absolute protection to the palms it occupies, and it has been observed in the plantations with captured *Amblypelta* adults ; nymphs would have no chance at all to survive on an *Oecophylla*-occupied palm. This ant also captures and kills two other pests of the coconut spadix, viz., the bug *Axiagastus cambelli* and the small weevil *Diocalandra taitensis*.

The same is true to a modified extent of the ant *Anoplolepis*. When six bugs were caged on a spadix in a tree occupied by this ant, *Anoplolepis* soon invaded the cage and caught and killed all the bugs within a few hours. The slower and smaller species, *Pheidole* and *Iridomyrmex*, will also destroy the bugs, when they can catch them. Our small cylindrical rearing-cages had to be made ant-proof, otherwise *Pheidole* would get in and kill both nymphal and adult bugs. In the larger cages and insectaries, the bugs were usually able to evade these ants.

An egg-parasite (*Anastatus* sp.) was hatched from an *Amblypelta* egg found by Lever on Kolombangara. During 1937, 1938 and 1939, Love has occasionally found parasitised eggs and has hatched three species of local egg-parasites from them ; one of these is probably identical with the insect found by Lever. No parasites of the nymphal or adult stages have ever been observed. From these data we may safely conclude that the control exercised by local parasites is negligible.

At an early stage of my researches it was noticeable that there was a very heavy mortality among *Amblypelta* in the rearing-cages, more especially when the bugs were rather crowded. In March 1936 (*i.e.* towards the end of the wetter or N.W. monsoon season), individuals collected from estates were observed to have an abnormal appearance. The nymphs of the third, fourth and fifth stadia were found to have the abdomen recurved ventrally and compressed dorso-ventrally. The adults had the posterior parts and sometimes the legs covered with small, white, oval bodies. These bodies consisted of an outer wall, inside which were numerous minute, white spores. Occasionally hyphae were noticed.

Individuals thus affected soon died. When apparently healthy bugs were placed with diseased ones, they usually became infected and died. Dr. Waterhouse, of Sydney University, examined some of these diseased bugs and found traces of what appeared to be an entomogenous fungus. As so few scientific workers have studied this type of disease, the fungus has not so far been identified.

Towards the end of May, the occurrence of diseased bugs became scarcer and at length ceased, so that it seems likely that the disease appears towards the end of the N.W. Monsoon and vanishes with the appearance of the N.E. Trades.

An interesting phenomenon, which may be associated with the fungus, was the sudden coming into bearing of an area of palms at Karikana and the disappearance of the bugs from it. This happened immediately after the fungus epidemic, *i.e.* in June 1936. I had visited this area previously in April and found that the nuts had all been falling in the " button " stage, *i.e.*, a few days after the spadix had opened. This indicated a more intensive attack than usual, which meant that there were more than the average number of bugs per tree. It is possible that this " crowding " of bugs during the wet season led to the fungus epidemic and killed most of the bugs, thereby stopping nutfall until the surviving bugs increased to harmful proportions again. In two or three months this area did, in fact, revert to its former barren condition. The same thing is said to have happened in this block about two years earlier, when the palms made a similar recovery. An analysis of the copra returns (by blocks) at Lunga, Guadalcanal, shows certain irregular fluctuations during the last few years, which may have been due to this cause.

Development of young Spadix and normal Nutfall.

Another advantage of the observation platforms was that the life of the spadix could be observed at frequent intervals. Directly a spadix bursts, the male flowers begin to open, starting at the apex of the distal branches and opening in succession towards the base. After flowering, these male flowers fall, the entire process lasting three weeks (*cf.* Sampson**[16]**, 12–15 days in Madras). The flowers are visited by bees and other pollinators. As soon as the last male flowers have fallen, the female flowers start to open and the honey-ducts surrounding them commence to exude nectar. This attracts bees and other insects, some of which are covered with pollen from the male flowers of other spadices. Actually these pollinators do not appear to be necessary, as caged spadices, to which all insects except very minute ones could not gain access, produced the normal number of nuts. It therefore appears that the nuts are (or can be) wind-pollinated.

As soon as the female organs have finished flowering—and this period lasts from two to five days (*cf.* Sampson, 12–15 days in Madras), a new spadix opens. Thus self-pollination can rarely occur. Occasionally, however, a new spadix does burst before the female flowers of the previous spadix have withered, and again, a new spadix may not burst till a week or more after its predecessor has finished flowering ; but these cases are exceptional.

Observations of a number of palms, over a period from mid-March to mid-July 1936 showed that an average of 23½ days intervened between the bursting of successive spadices, and that the interval between the bursting of the spadix and the blossoming of the female flowers averages 20 days. Coconuts produce spadices here all the year round.

During the latter part of 1938 and the earlier part of 1939, further observations of spadix-bursting were made to supplement our earlier data. Several hundred observations were made and showed that the average interval did not vary according to the time of year but remained constant at 23½–24 days. But there is considerable individual variation and instances ranged from 15 to 33 days, though the majority of spadices burst after an interval close to the normal time.

A spadix invariably produces a greater number of nuts than can be nourished by the tree, so that normally only about a quarter of them will become full-sized nuts, though this proportion is greater—say up to 50 per cent.—in the case of spadices with few nuts. This 50–75 per cent. wastage is called *normal* nutfall. The records of my observation trees show that these nuts usually start falling during the sixth week after the spadix has burst and stop falling after about the twelfth week. These normal nutfalls have a clean, unmarked shell, and when cut from top to bottom the interior has a healthy white appearance.

Nutfall due to Amblypelta (Plate XIII, fig. 2).

Fallen nuts that have been previously attacked by *Amblypelta* have an entirely different appearance from normal nutfalls. They have characteristic brown-stained areas at the stalk end. When the calyx is removed, irregular dark, longitudinal furrows mark the sites of proboscis punctures ; these are furrows and not pits, because the up-and-down motion of the bug's stylets saws a slit through the shell. Many of the nuts have a brown, jelly-like exudation at the base and the great majority have patches of white mycelium there and also in small cavities, caused by tissue shrinkage. When bisected longitudinally, the flesh is seen to be stained brown at the stalk end and occasionally throughout. Furthermore, there are internal shrinkages in the nut and it comes away easily from its surrounding calyx. Often such shells as are normally green become discoloured light to dark brown.

The effects of a bug-puncture are strictly local, *i.e.* confined to the particular nut attacked. For though the male flowers of the spadices and the portions of stem to which they are attached show numerous bug punctures, yet no immature nutfall is induced. This seems to indicate a toxin rather than a virus as the cause of injury transmitted by the bug, a theory supported by the healthy appearance of the rest of the tree. Another possibility is that nutfall is entirely a physiological reaction due to the mechanical effect of punctures or the withdrawal of sap by the bugs, but this is rather negatived by the characteristic traumatic and necrotic symptoms shown by *Amblypelta* nutfalls. Consideration of this aspect of nutfall led to inoculation experiments described later.

In contradistinction to normal nutfall, which, as noted above, rarely commences before the sixth week, *Amblypelta*-caused nutfall is nearly always completed by then, always assuming that the spadix has been sufficiently attacked by the bugs. In the case of the caged spadices on the observation trees, where each cage contained six bugs, nutfall started during the first week, the earliest falls occurring on the third day. By the end of the third or fourth week nutfall was complete.

Observations in the field, made some months later and described below, show that *Amblypelta*-induced nutfall takes about twice as long on plantation spadices and therefore suggests that the population density on these spadices is usually lower than that of the observation cages, a result supported by the population counts, described under a later heading. However, it should be borne in mind that the counts refer to the *observed* population, which is almost certainly considerably lower than the *actual* population.

On the other hand, the fact that nuts fell earlier in the cages than they do in the field may be due to the caging of six nymphs and adults on the spadix as soon as it had burst, so that the damage was inflicted at the earliest possible stage ; whereas in the field the spadix may escape attacks at first and only become punctured in course of time as the bugs find it, when perhaps the nuts are a little older and therefore resist nutfall somewhat longer.

Tests were therefore made with the object of classifying fallen nuts according to their size and type of injury—and inferentially the cause of their fall.

Sample plots, each containing six palms, were fenced off in typical nutfall areas, and the ground below them was cleared of all growth. The fresh nutfalls were collected daily, inspected and classified. The tests were carried out intermittently during 1937, 1938 and 1939, and aggregated several months in duration.

Of the nutfalls, 97 per cent. had the typical, dark, elongated depressions caused by *Amblypelta*, showing that this bug is the predominant cause of nutfall here. If it be argued that these injuries might be caused by *Axiagastus*, a bug which is far more numerous than *Amblypelta* in the plantations, the reply would be that *Axiagastus* is also common in the Russell Island estates, where parallel tests were made and and where no nutfalls of this type were found. Further, *Axiagastus* bugs were caged on spadices in tests, and though some nuts fell, they did not show injury marks of this type.

The remaining 3 per cent. consisted partly of " normal " nutfalls and partly of nuts injured by *Tirathaba rufivena* and other minor pests.

The classification of nutfalls in these plots according to size revealed that some 90 per cent. of them did not exceed two inches in length (with the calyx removed). By measuring the young nuts at different ages, it was found that a two-inch nut was, on an average, about six weeks old and therefore 90 per cent. of the nuts in *Amblypelta* areas fall before they are six weeks old. As shown under another heading, the bug population fluctuates somewhat, and the larger the population the smaller is the average size of a fallen nut, *i.e.* the more quickly is the fruiting-branch denucified. But when very young nuts are injured, they sometimes shrivel on the tree and do not fall.

Amblypelta Injury on other Plants.

When *A. cocophaga* is fed on potted legumes, such as peas and beans, the leaves become first blotched and twisted and then wither. Two dozen bugs were caged early in 1936 on a small garden shrub (species unknown) at Gavutu. Within a week all the leaves were withered and their stems and even small branches parted from the trunk at a touch. Dry rot was noticeable at the junctions and in some cases mycelium was present, small white globules appearing intermittently along the veins. " Rosetting " occurs when these bugs are caged on *Carica papaya*, and sometimes the smaller branches rot and fall. The stems and leaves of kapok are often twisted and shrivelled by the bugs' attacks and eventually fall off.

On the other hand, the bug punctures on citrus fruit cause only a local discoloration, and the effect on the wild host-plants also appears to be very slight. Thus, the leaves and stems of *Ficus* do not show more than slight signs of injury, though the fruits become discoloured and may drop off ; and the effect on *Macaranga tanarius* is confined to small discolorations of the leaf portions round the punctures and slight twistings of the stem. Mycelium does not appear, and this rather suggests that, where it has been noticed, it is that of a secondary fungus, which has attacked tissues already injured by *Amblypelta*, and that the actual cause of injury is *not* a fungus but some toxic substance contained in the bug's secretion.

Observations made on the injuries, inflicted by other bugs of this genus and of the closely-related *Dasynus*, would seem to support this hypothesis. An interesting feature in all cases being the slight damage suffered by the " wild " host-plant in comparison with the serious injury inflicted on the " adopted " host.

Causal Agency of Nutfall.

In an attempt to find out whether nutfall was due to something injected by the bug or to a secondary agency, the following experiment was carried out.

A number of freshly-burst spadices were selected and caged to prevent insect attack. Half of these spadices had some 50 per cent. of their nuts injected with an extract of the salivary glands of *Amblypelta* by means of a hypodermic needle. The remaining spadices had about 50 per cent. of their nuts punctured with an empty, sterile needle.

The results were not very enlightening. On one spadix of gland-injected nuts, characteristic *Amblypelta* nutfalls were caused, but all the others gave only what appeared to be an increased number of " normal " nutfalls which fell rather earlier than usual.

The spadices with nuts which had been punctured with an empty needle also yielded what seemed to be increased and accelerated " normal " nutfalls, except in one instance, where the nuts did not fall prematurely or in increased numbers.

The injections were not really satisfactory, partly because it was not possible to reproduce correctly the diameter and depth of an *Amblypelta* puncture with a hypodermic needle, partly because the bug's salivary glands are so small that a good deal of the body-fluid and other extraneous matter was included in the solution of macerated glands.

The only conclusion which could be drawn safely was that puncturing the nuts appears to hasten and increase the percentage of normal nutfalls, and that the pricked nuts are generally the first to fall. But the test also supported the probability that the proboscis of *Amblypelta* conveys the actual causal agent of this type of nutfall and that this agent is *not* something which enters the puncture after it has been made. For if it came in afterwards, it might fairly be expected to have entered the punctures made by an empty needle, too, and caused the usual immature nutfall symptoms ; and this was not the case.

Recent experiments with caged *Axiagastus* have also given a slightly accelerated and increased type of normal nutfall, and this rather confirms the view that there is something toxic in *Amblypelta's* salivary secretion which causes the special type of nutfall induced by this bug.

Experimental Measures to protect the Nut.

In the initial phases of the investigation, when it was believed that nuts were only susceptible to attack during the earlier stages, the possibilities of protecting them during this period were considered and tested.

I had accidentally come across an *Amlypelta* nymph which had become entangled on a tree with viscid sap, and this suggested that if the nuts were sprayed or brushed with a sticky substance during their " susceptible " period, they might be immune from attack. By using a dope, the effects of which would be sufficiently lasting, it would only be necessary to make one application per spadix.

Using a type of tropical tanglefoot, the cost of labour and material worked out at one shilling and twopence per tree per year ; and, although this would not have been economic as a general measure of control, it might have been worth while as a temporary expedient, pending more satisfactory methods. In particular, it might have been of value as a barrier-belt in places where nutfall was advancing.

Accordingly a test was made during March 1936 on Tananbogo, using 12 cages, each containing 6 bugs and a spadix, the nuts of which had been brushed with the protecting dope. It proved a pronounced success, an average of only 46 per cent. nutfall being recorded. But when the dope was used in the nutfall area on Guadalcanal, the results were not so satisfactory. In this case the spadices were not caged and heavy rains seem to have washed off some of the protective preparation, and the nuts all fell.

However, in the meanwhile, it had been found that the idea of a *limited* period during which the nuts were susceptible to attack was a mistaken one, and that nutfall might be induced during at least the first sixteen weeks of the life of a spadix and possibly longer. This meant that not one but several spadices would have to be protected on each palm, and that the dope would have to be applied several times to the same spadix. As this would have been far too expensive, no further tests were made.

At the suggestion of Messrs. Levers' London H.Q., an area of their estate at Lunga (Guadalcanal) was selected to see whether bugs could be starved out of it by cutting off all the spadices therein for a period of six months. This experiment was made, during my absence in the East Indies, by my assistant.

As *Amblypelta* feeds on a number of undergrowth shrubs and, further, as bugs could always move in to the plot from adjacent areas of plantation or bush, the prospects of success were slight. Moreover, many of the eggs are laid on the central leaf-spike of the palm, and nymphs may be found there, too.

At the end of the six-monthly period, the spadix-cutting ceased and the palms were allowed to bear again ; but the area soon became re-infested by *Amblypelta*. When this plot was re-inspected six months after spadix-cutting had ceased, it had become a typical nutfall area again, indistinguishable from the adjacent areas.

Other Types of immature Nutfall.

Scattered through the Group may be found cases of nutfall that do not appear to be associated with *Amblypelta*. At Segi, in New Georgia, such an area was seen where the nuts were covered, inside and out, with colonies of mealy-bugs, fostered by the ant *Pheidole oceanica*.

Then there are the partly-grown nuts, often found on the ground, the shells of which are constricted by parallel, irregularly circular lines, like crinkly parallels of latitude, and other nuts which have become elongated or even banana-shaped. These may be due to physiological causes or soil conditions.

More important is the type of nutfall due to the caterpillar of the Pyralid moth, *Tirathaba rufivena*, which may be recognised by the exit-hole it leaves, usually at the calyx end, and by the caterpillar's frass.

A certain amount of nutfall is also due to rats, and the large holes they gnaw are easily recognisable. *Axiagastus cambelli*, a bug often fairly numerous on the spadices, may, it seems likely, increase the amount of " normal " nutfall by its drain on the sap.

There are doubtless other minor causes of nutfall, but it is not probable that any of them are of real importance ; for if one or two nuts on a spadix are injured and fall during the first few weeks after it opens, more sustenance is available for the remaining sound nuts, and consequently the amount of " normal " nutfall is less than it would otherwise have been. Thus, the total crop of a spadix is not affected by the dropping of a few nuts during its early life.

Discussion.

The conclusions derived from the experiments and observations summarised in the foregoing pages were as follows :—

Amblypelta cocophaga is the main agent responsible for immature nutfall in the Solomon Islands. The bug probably came from the bush, and the area of invaded plantations is slowly spreading.

An observed population of less than two bugs per tree is sufficient to render an area non-bearing. Of the fallen nuts found in " nutfall areas " 97 per cent. show the typical signs of *Amblypelta* injury. About 90 per cent. of the nuts fall before they are six weeks old.

As bugs can successfully attack nuts up to at least 16 weeks old, and as the bugs may be found on parts of the palm other than the spadices and also on various undergrowth plants in the plantations, any form of mechanical or chemical control is likely to be ineffective and certain to be far too expensive. Thus biological control remains the only possible measure we might usefully employ.

Local biological controls include three egg-parasites, one predatory bug and four species of ants, in addition to an entomogenous fungus. All these seem to be comparatively ineffective except two ant species, which give almost complete control on the palms they occupy. Unfortunately these are being slowly driven out of the plantations by two other species, which are unable to control *Amblypelta*. The spread of nutfall proceeds as the beneficial ants are ousted by the intruding species.

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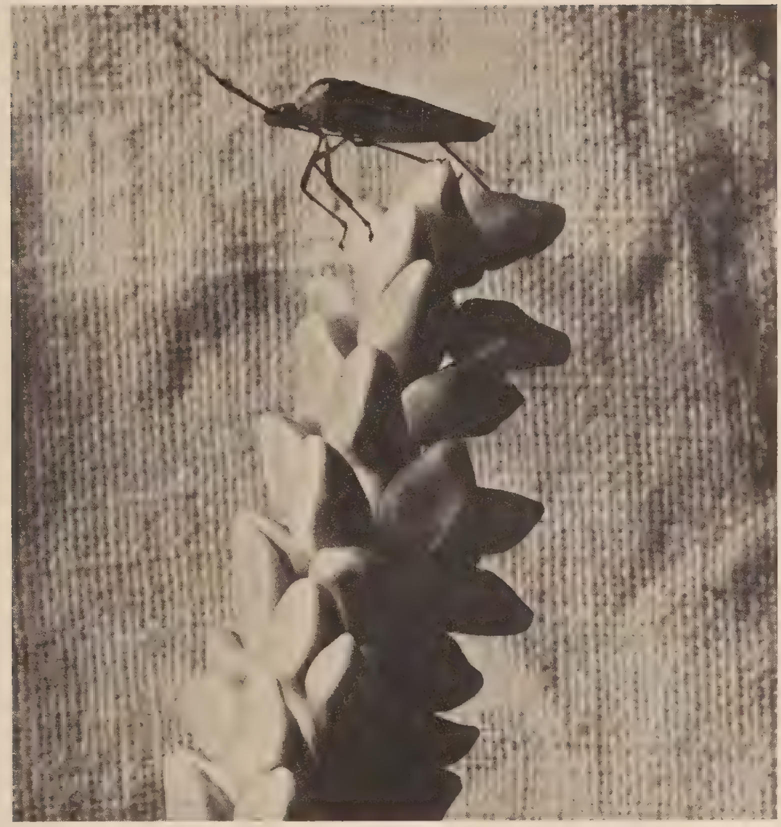

Fig. 1. *Amblypelta* on ♂ flowers of a new spadix.

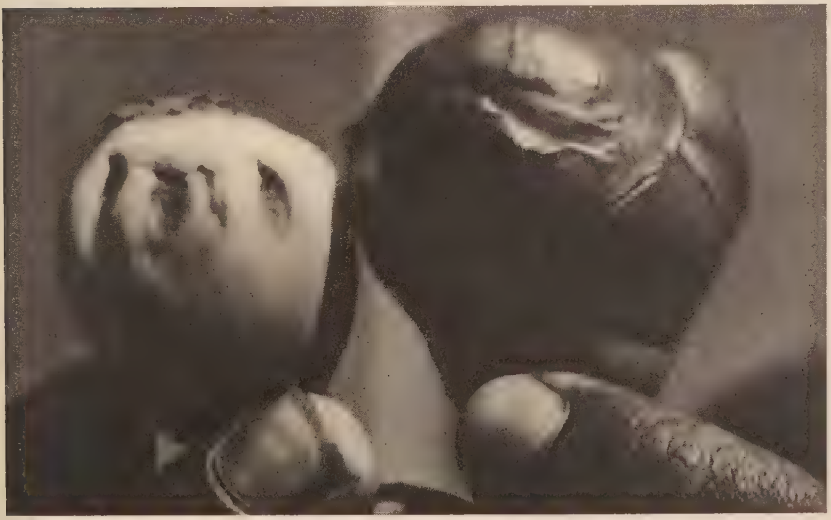

Fig. 2. Young coconuts injured by *Amblypelta cocophaga.*

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between the 1st April and the 30th June, 1940.

Agricultural Research Institute, Wad Medani :—145 Coleoptera, 64 Lepidoptera, 115 Orthoptera, and 2 Mites ; from the Sudan.

Mr. W. Allan, Entomologist :—28 Parasitic Hymenoptera ; from Northern Rhodesia.

Mr. G. A. Bisset :—11 Coleoptera and 9 early stages ; from England.

Dr. F. S. Bodenheimer :—6 Tabanidae, 92 other Diptera, 1,047 Coleoptera, 26 Parasitic Hymenoptera, 220 other Hymenoptera, 21 Lepidoptera, 207 Rhynchota, and 9 Dermaptera ; from Turkey.

Prof. P. A. Buxton, London School of Hygiene and Tropical Medicine :—187 Diptera ; from Uganda.

Mr. J. Carroll :—1 Lepidopterous larva ; from Ireland.

Chief Entomologist, Pretoria :—4 Diptera, 29 Coleoptera, 170 Parasitic Hymenoptera, 8 Lepidoptera, 5 Rhynchota, and 4 Orthoptera ; from South Africa.

Chief Plant Protection Officer, Jerusalem :—60 Diptera, 11 Parasitic Hymenoptera, 90 Lepidoptera, and 4 Mites ; from Palestine.

Mr. A. W. Cleaver :—20 Coleoptera ; from England.

Mr. G. H. Corbett, Government Entomologist :—2 *Tabanus*, 61 other Diptera and 16 pupa cases, 224 Coleoptera, 64 Parasitic Hymenoptera, 31 other Hymenoptera, 130 Lepidoptera and 77 pupa cases, 68 Rhynchota, and 11 Orthoptera ; from Malaya.

Director of Agriculture, Mauritius :—118 Diptera, 5 Coleoptera, 28 Parasitic Hymenoptera and 18 cocoons, 10 Lepidoptera, 2 Rhynchota, and 1,000 Mites ; from Mauritius.

Mr. R. G. Fennah, Entomologist :—41 Curculionidae ; from the British West Indies.

Mr. R. L. E. Ford :—3,000 Parasitic Hymenoptera ; from England.

Forest Products Research Laboratory :—1 Coleopterous larva ; from England.

Mr. J. L. Froggatt, Government Entomologist :—4 Diptera, 78 Coleoptera, 9 Parasitic Hymenoptera, 3 Lepidoptera, 1 species of Aleurodidae, 23 other Rhynchota, and 3 Orthoptera ; from New Guinea.

Game Warden, Nairobi :—35 Dipterous larvae, 3 Coleopterous larvae, 350 Ephemerid larvae, and 105 Trichoptera larvae ; from Kenya Colony.

Mr. J. C. M. Gardner, Systematic Entomologist :—189 Diptera and 8 pupa-cases, and 9 Lepidoptera ; from the United Provinces, India.

Mr. F. D. Golding, Government Entomologist :—16 Coleoptera, 5 Lepidoptera, 13 Rhynchota, and 18 Orthoptera ; from Nigeria.

Government Entomologist, Coimbatore :—21 Coleoptera, and 9 Lepidoptera ; from South India.

Mr. H. Hargreaves, Government Entomologist :—18 Formicidae, and 2,500 Isoptera ; from Uganda.

Mr. G. H. E. Hopkins, Medical Entomologist :—2 *Stomoxys*, and 7 other Diptera ; from Uganda.

Institute for Plant Diseases, Buitenzorg :—12 Parasitic Hymenoptera; from Java.

Dr. G. Jannone :—51 Orthoptera; from Italy.

Mr. R. A. Lever, Government Entomologist :—7 Culicidae, 3 Tabanidae, 71 other Diptera, 29 Coleoptera, 128 Parasitic Hymenoptera, 19 Lepidoptera, 5 species of Coccidae, 13 other Rhynchota, and 4 Orthoptera; from the Fiji Islands.

Mr. C. L. Liu :—6 Coleoptera, 3 parasitic Hymenoptera, 4 Moths, and 1 species of Coccidae; from China.

Mr. E. McC. Callan :—22 Parasitic Hymenoptera; from Trinidad.

Prof. P. Maréchal :—3 Coleopterous larvae; from Belgium.

Mr. N. C. E. Miller, Entomologist :—18 Trypetidae and 4 slide preparations; from Malaya.

Mr. E. F. Peck, Veterinary and Agricultural Officer :—1 Spider; from British Somaliland.

Dr. A. Shulov :—149 Diptera, 524 Coleoptera, and 2 Parasitic Hymenoptera; from Palestine.

Mr. E. R. Speyer :—6 Coleoptera and 10 larvae; from England.

Mr. F. A. Squire, Government Entomologist :—6 Culicidae, 18 other Diptera, 5 Coleoptera, 300 Formicidae, 8 Lepidoptera, 13 species of Coccidae, 8 species of Aphidae, 37 other Rhynchota, and 100 Ticks; from Sierra Leone.

Mr. J. Suire :—15 Parasitic Hymenoptera; from France.

Mr. C. B. Symes, Medical Entomologist :—119 Tabanidae, 14 *Auchmeromyia*, 4 *Cordylobia*, 4 Hippoboscidae, 951 other Diptera, 24 Coleoptera, 4 Parasitic Hymenoptera, 25 other Hymenoptera, 80 Lepidoptera, 31 Rhynchota, 3 Psocidae, 4 Orthoptera, 3 Planipennia, and 2 Trombidiidae; from Kenya Colony.

Mr. A. S. Talhouk :—1 Scolytid, and 6 Parasitic Hymenoptera; from Syria.

Mr. F. Wilson :—11 Parasitic Hymenoptera, and 2 Lepidoptera; from France.

Mr. F. E. Wilson :—1 Curculionid; from Victoria, Australia.

Zoological Institute, Ankara :—311 Orthoptera; from Turkey.

A PHYSIOLOGICAL STUDY OF MOSQUITO LARVAE WHICH WERE TREATED WITH ANTI-MALARIAL OILS.*

By G. I. Watson, M.A., M.D., M.R.C.S., D.T.M. & H.

Preface.

On 25th August 1914, the medical officer in charge of a rubber estate in Malaya wrote to the manager a report about a new method of polluting Anopheline breeding-places : " It will interest your Directors to learn that by oiling with the mixture in use on Sungei Way, one of the ravines in the West Divisions has been kept free from *Anopheles* for several months. Formerly they bred freely in it. I am encouraged to think that this is not merely due to the physical difficulty the larvae would have of getting air when oil is on the water, but that some change has actually taken place in the water as a consequence of the oil, and a change which would make it uncongenial to the stream-breeding mosquito. My reason for thinking this is that in the bottom of the ravine a green slime has developed, in the presence of which I have never found dangerous anophelines " (Watson, M. 1921). Before 1914 oil had been used on standing water, and poisons had been used in running water (Howard, Dyar & Knab, 1912) to reduce the breeding of mosquitoes. But this discovery, that it could be effectively and economically used even on fast-flowing streams to control *Anopheles*, made the use of oil *par excellence* the great standby in emergencies of malaria ; while it may be the method of choice if control measures are only required for two or three months in each year.

"Any oil or mixture of oils will not give this result. We soon found that what is sold as ' crude oil,' or ' fuel oil,' or ' diesel oil,' varies greatly in composition in different parts of the world, and that many of these oils do not make satisfactory anti-malarial mixtures. Some would not kill larvae, some would not kill grass, some would not spread, some required the admixture of uneconomical amounts of kerosene, and some were quite useless. . . . . The health officers of one Government, who could draw large supplies of used aeroplane oil for anti-malarial purposes, found even this so unreliable that each sample had to be tested before it could be used, and owing to the results being so variable they gave up using the aeroplane oil " (Watson, M. 1938). The same writer goes on to utter a word of warning against using other home-made mixtures, which may vary in composition and may prove a false economy if the ingredients are not tested to find if they are efficient.

The aim of the Ross Institute, expressed in its Annual Report for 1936/37, has been to arrange that every part of the tropics should have on the market an " anti-malarial mixture of a definite composition and proved efficiency." But it was clear that there still existed many gaps in our knowledge of how oil affects the waterbound stages of mosquito life, and that before this aim could be fulfilled many questions needed an answer. For instance, why do some oils act better than others ? What is the nature of the change produced by oil on water in a stream, which allows one type of vegetation to replace another, while one type of insect is driven from the stream although others can and do remain ? Are all the effective oils necessarily expensive, and *vice versa* ? Within what limits can and should reliability of an oil be maintained ? What tests are to be applied to see if an oil sample is up to standard ?

This paper is an attempt to answer some of these questions.

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* Extracted from a thesis for the M.D. degree, read and published at The University, Cambridge, on 23rd February 1940.

Aim of Experiments.

The aim of these experiments was, first, to examine and record the behaviour of mosquito larvae while they were in contact with oil or in contact with water that had been treated with oil ; secondly, to note any variations in the behaviour of such larvae from that of normal larvae ; and thirdly, with the help of the records to try to link up these variations with the properties of different oils or of the treated water. The ultimate object was if possible to increase the efficiency and so lower the costs of anti-malarial oil mixtures.

General Technique.

Briefly, the larvae were observed microscopically while oil was put on the water in which they were living. Records were kept of their behaviour before, during and after oiling and great care was taken to help the treated larvae to survive, to moult, and if possible to pupate and hatch. The dose of oil was often less than that used hitherto in field experiments, and an attempt was made to define the smallest dose of certain oils which the larvae could tolerate. Moulting, pupation and emergence were all seen in some of these treated larvae.

Apparatus.

The following apparatus is required if full value is to be got from experiments such as these. Nevertheless, with less elaborate material, which would still allow oil to be tested locally, much information could be gained and local anti-malarial mixtures might be devised or improved.

A good plain microscope is required, though a dissecting microscope does nearly as well, but is more tiring to work with. The microscope should have 1 in. and 2/3 in. objectives, with eye-pieces magnifying 6 times and 10 times. A mechanical moving stage is almost a necessity for reasons set out below. The type of stage used for these experiments was one where the upper surface was large enough to take dishes of many sizes and shapes, but on some stages this would not be possible.

The following dishes were used for storing the larvae. In the insectary of the Entomological Department the larvae were reared in large earthenware pans. As required, the larvae were transferred into a porcelain dish, diameter 17 cm., glazed on the inner surface. As many as a dozen larvae might be kept in this dish at one time.

For the oiling experiments larvae were transferred into smaller dishes of cheap optical glass. Each dish was 5·5 cm. square by 2 cm. deep. The bottom of the dish was smooth. The upper surface was hollowed but not optically smooth ; when the dish contained water there was, however, no distortion of the light by the irregularities of this concave surface. The measurements of the concavity were : diameter 4·7 cm., depth 1 cm., and convenient content about 7–10 ml. Each individual larva was put into such a dish as this, where it could be observed microscopically throughout the experiment.

Each larva was given a serial number, and this number was marked in blue pencil on the glass dish containing it, so that any possibility of mistaking the larvae was avoided.

To reduce evaporation of the water in these dishes, they were covered with lids of square plate-glass, one corner of each raised on a pledget of cottonwool. This allowed enough air to reach the larvae for controls to survive and develop normally.

Some method of keeping the larvae at a suitable temperature must be devised if they are to have the optimal conditions in which to survive after treatment. At first I used to return the larvae in their dishes to the insectary, but later found by experiment with controls that an ordinary incubator set at 32–33°C. sufficed if wide dishes of water were exposed within to supply the moisture for evaporation. In some parts of the world natural conditions may make these precautions unnecessary.

Larvae were transferred from dish to dish by means of wide-mouthed pipettes. These were of 8 mm. glass tubing fitted with a rubber teat. One clean pipette was kept for dipping into the porcelain dish where unoiled larvae were, and another was kept for handling the oiled larvae. It is important at once to wash this pipette thoroughly after it comes in contact with oil. For moving larvae about within the dishes, either when they have fallen from the surface or for other reasons, fine-drawn pipette ends (see below), sealed so that they are blunt, are very convenient.

Water.

Tap-water in London evaporates when kept in dishes in the incubator, so that crystals appear both on the surface and at the bottom of the water. If a larva is in such water, crystals grow on its hairs, and sometimes the concentration of salts becomes sufficient to damage the anal-gill mechanism which controls the larva's water intake (Wigglesworth, 1933). Such larvae, though they may survive and moult, are under slightly adverse conditions. So in the later experiments only distilled water was used.

In some experiments, the aim was to see if water-soluble toxins dissolved out of an oil in sufficient amounts to poison a larva.

The method, for which I am grateful to Professor P. A. Buxton, is as follows :—

> A wide filter funnel (diameter 10 cm.) with a rubber tube and clip was filled with water. Oil was then poured on to the water surface and the whole thing was left for a while, perhaps a day or a week according to the experiment. It may be necessary to cover the funnel with paper to lessen evaporation.
>
> As required, samples of water could be withdrawn through the rubber tube without disturbing the oil film. This water was either added to water in the larva's dish, or else was used undiluted, the larva being transferred to it in a second dish.

Another method, applicable only to a few oils which are heavier than water, is to drop the oil into a dry dish, then add water gently and put the larva into it. The oil remains at the bottom and the larva comes into contact only with any water-soluble toxins. Note that when experimenting with Culicine larvae feeding on the bottom, a larva may come into direct contact with a heavy oil at the bottom of the dish.

Food.

The larvae were fed with small amounts of the following mixture : dried dog biscuit, dried earth, brewer's yeast, dried powdered bread. Some of this was dusted on the water in the dishes once or twice a day, but only if the surface of the water had been quite cleaned by the feeding larva ; none was added if the surface of the water was still dirty with food particles. One tends to overfeed larvae rather than the reverse, and in particular is this true of the pre-pupating larvae. If this is done, the insect may become heavily infested with parasites and may fail to pupate.

Oil.

The oil was supplied by Technical Products, Ltd., in 1 gallon tins with screw caps. These were only opened when a sample of oil was removed into a 10 ml. measuring cylinder or into a test-tube. Only a few ml. of oil are needed at one time. If an oil is left exposed to air, changes may occur which markedly affect its value as an anti-malarial larvicide.

The oil was transferred with wide-mouthed or fine-drawn pipettes, according to its viscosity. But when applying oil to the dishes in which the larvae were, only fine-drawn pipettes were used. These delivered on an average 30–50 drops of oil per ml. The end of such a tube was drawn out into a long capillary and was broken off. These ends were kept and are useful for other purposes.

As a general rule oil was applied gently to the surface of some part of the water where the larva was not resting. But occasionally for special purposes the oil was dropped directly over the larva's tail.

Partial Oiling.

At this point a word will be said about the technique which I have called "partial oiling," that is, so oiling a larva that oil does not completely replace the air in both tracheae, but enters perhaps only part of one trachea. Occasionally this effect is seen when oil is dropped directly over the tail of a larva. More certainly it is obtained by emulsifying a little of the oil in plain distilled or tap water, and then dropping some of this emulsion on the resting larva's tail. The larva is examined after each drop to see if any oil has entered either trachea ; sometimes oil entry is seen with the first drop. If the oil spreads out as a film after many drops of emulsion have been added, it is best to change the water and begin again.

Most oils float on water, and a convenient way of emulsifying them is to squirt the oil and water up and down in a cylinder or test-tube. Then after leaving the oil globules to rise for about five minutes, fill the pipette from the lower part of the emulsion where the finest globules are still suspended. For it is one or two of these fine globules only that are to be introduced into the larva's trachea.

Spread of Oil on Water.

The spread of oil on water is governed by the forces of surface tension. There are three surfaces concerned : that between water and air, that between oil and air, and that between oil and water. By its surface tension, each one of these surfaces tends to reduce its area at the expense of the other two. Whether oil spreads on water or remains as a lens will depend on whether the forces tending to reduce the two oil surfaces are together greater or less than the one force tending to reduce the water/air surface. The tension of this water/air surface is usually great ; the tension of the oil/air surface is usually small ; the tension of the oil/water surface may be greater or less than the difference between the other two tensions. If it is greater, the two oil tensions will overcome the one water/air tension and the area of the two oil surfaces will remain small ; if it is less, the single water/air tension will overcome the two oil tensions and the water/air surface will be reduced at the expense of the two oil surfaces. In the former case the oil will remain as a lens, in the latter the oil will be spread out as a film.

The effect of this interplay of tensions was studied in the laboratory by letting one drop of an oil fall from a fine pipette on to water in a dish 10 cm. square. This was calculated to be roughly equivalent to 10 pints of oil per acre of water.

The water used was either clean tap-water which had overflowed the sides of the dish (high surface tension) or tap-water run into a slightly greasy dish, or water whose surface had been dusted with larva food (lower surface tension). The effect of dust falling on a film or lens of oil was studied by letting a few grains of larva food fall from a knife-point on the oil.

The object of such experiments was to examine the spread of any oil under favourable and unfavourable conditions. A variety of types of spread were noticed and these were grouped as follows :

(*a*) Initial small lens on clean water.
(*b*) Small lens, spreading when dust falls on oil.
(*c*) Initial wide, flat lens on clean water.
(*d*) Initial flash spread without iridescence on clean water.
(*e*) Initial flash spread with iridescence on clean water.
(*f*) Initial flash spread on dusty or oily water.

In general if two oils are dropped one after the other, side by side, on the same surface of water, the oil with the wider spread on clean water will expand at the expense of the oil with the less wide initial spread. And dust on the water surface limits the spread of any oil to an area smaller than that of its spread on clean water ; while dust falling on oil on a water surface increases the area of the oil surfaces and makes the oil spread better.

Washing and After-Treatment.

After oil had been added to a dish containing a larva and had come in contact with its body or had entered its tracheae, the larva might be left in the dish with the oil to see the effect of prolonged contact on the survival of a larva. Or, as soon as oil was seen to enter the tip of even one trachea, the larva might at once be spilled into a deep bowl of clean water, usually tap-water at 30°C. If much oily iridescence appeared on the surface of the bowl, a second change of water was made. Then the larva was pipetted into distilled water in a small optical glass dish.

Commonly a larva would be kept in the incubator if not being examined. In those which survived many days, it was found advisable to change their water completely each three or four days ; if not, a growth of parasites might become established in the dish, in spite of active feeding by the larva.

Attempts at aerating the water by blowing bubbles through it out of a fine pipette did not seem to help the larvae, and were abandoned.

Microscopy.

These are a few notes briefly recording certain further points in the technique of actually observing the larvae.

A low magnification is most useful for general work. This should allow nearly the entire larva to be observed at once. But in order to become familiar with all phases of normal and abnormal pulsation in the larval heart, every opportunity should be taken of examining any segment of a larva where this is clear with the highest possible magnification.

For low-power work in the stages while the heart beat can be easily seen, the lighting should be bright but the diaphragm stopped down. In the last stages, when the heart-beat is difficult to see in certain positions of the larva, less light makes easier the perception of faint movements within the larva.

The smaller the surface of water in the dish, the easier it is to observe the larva in the moments after it has touched the oil. But if the surface of water is extremely small, besides upsetting the larva's position, a comparison is no longer possible with the dose of oil used in field experiments.

A larva at rest in a dish is sometimes easily disturbed by the dish being moved jerkily. Therefore, as far as possible the dish should be moved very gently by means of the mechanical stage. But there is a time just after a larva has recently touched certain oils or after any oil has begun to enter a trachea, when the movements of the larva become so frequent and violent that the dish must be moved by hand, if a glimpse of the larva is to be obtained.

When an Anopheline larva is at the bottom of the dish, for instance, in the later stages after being oiled, it usually lies upside down. In this position the lateral and tail tufts are not against the glass, and the larval body is in a position of stable equilibrium ; when on its side or abdomen resting on its tufts, there is always a tendency for the larva to overbalance. It is not easy to observe the heart-beat of a larva which is lying upside-down, because of the irregularities of its ventral surface. These interfere with accurate definition with the microscope, so that the appearance of the inside of the larva is distorted.

Records.

It is essential in this type of work to make accurate records at the moment of observation. Short notes, line drawings quickly made, and a note of the time of events serve later to refresh one's memory. During quieter moments when the larva's condition is changing but slowly, time can be found to amplify the original notes and to record one's views, anticipations or comments on the events that have recently occurred.

A clear and full record of what the larva looked like before the experiment begins will ensure that all abnormalities of the larva are distinguished from subsequent effects of the oiling. In particular it has been found necessary to record specifically the appearance of the tracheae in the 7th and 8th segments, whether they are dark with air ; for in some earlier experiments I was unable to be sure that certain abnormalities seen after oiling had not perhaps been there from the first.

Between the time that oil is put on the water and the first appearance of oil in the tracheae, observation should be frequent if not continuous, so that if possible the exact time and manner of the oil entering may be seen. Sometimes when the moving meniscus of oil in the tracheae has not been seen, nevertheless the arrival of the oil soon afterwards into the fine branches in the neck and head can be awaited and observed. This may occur as long as one or two minutes after oil first enters the spiracles, but usually it happens sooner.

In order to simplify the keeping of these records, a sheet may be drawn up with space for the necessary information, and when this is filled up it contains all the relevant observations. There are three main headings under which observations can be grouped ; those made before oiling, those made during and immediately after the larva is in contact with oil, and those made of its subsequent behaviour and appearance.

It is not wise to throw out a larva as soon as it is pronounced dead, for it sometimes happens that postmortem changes occur, which confirm one's previous observations, or which are interesting on their own account. Of special interest, particularly in the early stages of the work, are records of the parasites found on living and dead larvae and in the water containing them. Since not much information is available in the literature about these parasites (Senior White, 1926), records from many parts of the world would perhaps be of value to other workers. Furthermore, as these animal and vegetable forms are one of the sources of food for larvae, at least under artificial conditions, a study of the effect of oil on these organisms is not without value when one is assessing the anti-malarial properties of an oil.

It has been found convenient to assemble the records of many larvae treated with the same oil, and to re-enter on another sheet within a special framework, certain information about each oil. In this way the records gain in value, for the facts about any particular oil are together and more accessibly arranged.

TABLE I.

How Oil in Contact with a Larva may disturb each of its Vital Functions.

Results Possible with any Oil :

Tissue oiled.	Function disturbed.	Possible result.
Externally :		
Body and hairs oily	Balance at surface	Wrong positions.
Feeding brushes matted	Feeding	Starvation.
Tail plate irritated mechanically, leads to "tail cleaning"	... ...	Oil enters tracheae.
Internally :		
Gut—after feeding on oil	Peristalsis	No effect.
Tracheae	Rising to surface	Drowning.
Tracheae	Respiration	Suffocation.
Tracheae	Moulting	Failure to effect the change.
Tracheae	Pupating	Failure to effect the change.

Results seen only when the Oil contains Water-soluble Toxins :

Tissue oiled.	Function disturbed.	Possible result.
On Larva :		
Feeding brushes	Muscles	Convulsion, paralysis.
Body wall	Skeletal muscles	Convulsion, paralysis.
Body wall	Heart muscle	Paralysis.
Anal gills	Control of water intake	Necrosis of gills.
Tail plate irritated by toxins leads to "tail cleaning"	... ...	Oil enters tracheae.
Gut—after feeding on oil	Peristalsis	Hyperactive, prolapse, paralysis.
Tracheae	Heart muscle	Paralysis.
On Water :		
Micro-organisms	Larva's food supply	Killed.
Plants	Larva's shelter	Killed.

TABLE II.

Spread of Oil and Chance of Larva being oiled.
(Larva at bottom, rising to strike oil.)

No.	Type of spread	Interval between larva reaching surface and touching oil	Interval between larva reaching surface and oil entering tracheae
B.5	Flash	Less than 1 min.	1 min.
B.7	Flash	Less than 2 mins.	2 mins.
B.10	Flash	Less than 1 min.	1 min.
B.11	Flash	Less than 1 min.	2 mins.
B.13	Flash	Less than 1 min.	1 min.
B.55	Flash	Less than 1 min.	1 min.
B.22	Large lens with dispersion film	3 mins.	5 mins.
B.32	Large lens	4 mins.	7½ mins.
B.33	Emulsion with droplet film	18 mins.	58 mins.
B.36	Emulsion with droplet film	1 min.	13 mins.

The Anti-Malarial Aspect of Differences between Oils.

The control of malaria is a local problem. If we would devise efficient measures for reducing the malaria in any region, we must have among other things an exact and detailed knowledge of the habits of the local *Anopheles*. Oiling the breeding-places of the carrier species has repeatedly been found to be a practicable measure. But two things have long delayed its use in a number of controlled areas. The first is the relatively high cost of oils hitherto as a recurring charge in expenditure on anti-malarial work. The second is the multiplicity of standards by which to judge the value of any mixture of oils. This multiplicity has followed from a lack of detailed knowledge about the action of oil on mosquito larvae. While " the doctors disagreed " it was left for the oil companies to try to meet different standards as cheaply as they could. And loss of sales was sometimes their first indication that oils, mixed according to a given formula in one part of the world, might not in fact form an efficient mixture when used in another part of the world.

The local breeding-place we have to deal with may be for instance a pond or a stream. When we consider oiling as an anti-malarial measure we have to decide how long an exposure to the oil we may expect the larvae to have.

Larvae in a pond will have a much longer exposure to a surface film than larvae in running water. Oil which killed only slowly by suffocation might, provided there was but little wind, prove as valuable on the surface of a pond as any of the more toxic oils. But for running water, where larvae may only take in small doses of oil, we should probably be wiser to choose an oil mixture sufficiently toxic to kill larvae before they can moult. That must be the measure of the time at our disposal.

Before we can decide whether to suffocate or to poison the larvae, or to kill them by poisoning their food or damaging their shelter, we must have studied the cost and the properties of the oils that are available locally. Up till now certain relatively expensive oils have commonly been added to cheaper mixtures on the assumption that some valuable property in the expensive oil was a necessity in the final mixture ; yet the addition of one of the " lighting " kerosenes might actually lessen the value of a mixture for anti-malarial purposes. An example will be described which may illustrate more clearly how useful this laboratory examination of local oils may yet become.

An Example of constructing an Anti-Malarial Mixture from Oils available locally.

The Ross Institute was asked to examine a mixture of three local oils and to report on its value as an anti-malarial oil for spraying on local breeding-places. These breeding-places were mainly in slowly running streams with some vegetation along the edges. The three oils and the prices at which they were locally available were as follows :

Oil.	*Type.*	*Cost per English ton (decimal).* £
" WC " ...	Kerosene ...	28·0
" XC " ...	Fuel oil ...	5·0
" ZD3 " ...	Heavy oil ...	5·5

The formula of the mixture we were asked to examine was as follows :

Oil.	*Volume.*	*Cost in £ (decimal).*
" WC " ...	6	1·7
" XC " ...	77	3·9
" ZD3 " ...	17	0·9
Total ...	100	6·5 per English ton.

Summary of Experiments with these three Oils.

Kerosene " WC " :—Poor spread on clean water, slightly better on dirty water with surface particles. Not sticky at all. Not very irritating. Toxicity moderate (killing time 2–6 hours).

Fuel Oil " XC " :—Very good spread on clean and good spread on dirty water. Not sticky. Hardly at all irritating. Toxicity moderate (killing time 3–7 hours).

Heavy Oil " ZD3 " :—Slow spread to wide lens on clean water, less good on dirty water. Very sticky. Irritation possibly due to stickiness. Toxicity not clearly determined (one larva survived 24 hours).

Mixture 1 :—Spread good on clean water but not good on dirty water. Stickiness not marked (brushes cleared of oil in 3 hours). Toxicity slight to moderate (more than 2½ hours).

For some reason, unknown at the time of the investigation, the toxicity of the kerosene " WC " was not very different from the toxicity of the fuel oil " XC." Therefore a new formula was suggested leaving out the kerosene to save expense, and reducing somewhat the amount of heavy oil " ZD3 " which was present only for its dark colour and its stickiness.

The following is the proposed new formula :—

Oil.	*Volume per cent.*	*Cost in £ (decimal).*
" XC " ...	90	4·5
" ZD3 " ...	10	0·6
Total ...	100	5·1 per English ton.

Summary of Experiments with the new Mixture.

Mixture 2 :—This oil spreads very well on clean and well on dirty water. It is fairly sticky. It is not irritant. Its toxicity is slight to moderate, possibly slightly less than " XC " alone.

The advantages of Mixture 2 as compared with Mixture 1 were :—(*a*) About 20 per cent. cheaper ; (*b*) better spread on clean and dirty water ; (*c*) slightly more sticky.

Its disadvantages were :—(*a*) Slightly less toxic ; (*b*) slightly less irritant.

The reason for the low toxicity of the kerosene " WC " was learnt later. It had been very highly refined for burning in chimney-less lamps which were common in the locality. It burned with a smokeless flame as a result of certain aromatics having been removed. By this process some of the substances which are toxic to Anopheline larvae had also been removed. These experiments taught the lesson that one kerosene is not as good as another, from the point of view of anti-malarial oils. And if someone in another part of the world, without examining the toxicity of the local kerosene by some such technique as is here described, suggests " adding a little kerosene to the mixture to make it more efficient " he may be merely raising the cost of his mixture without gaining any advantage.

Discussion.

The discovery of any improved technique in scientific work usually opens new fields for study. The experiments recorded in this paper are perhaps the first results obtained by a new technique. And yet in one sense there was in fact nothing new about it, for at any time anyone who chose could have closely and continuously watched larvae dying in contact with oil.

It has never been suggested that laboratory experiments such as here described can replace field tests as the ultimate proof of the value of an anti-malarial mixture. My aim has been, if possible, to learn more of the reasons why a mosquito larva dies when in contact with oils.

The result of this research has been to show not only that a larva after contact with an oil may meet its death in several ways, but also that in certain circumstances it may, after being oiled, escape death by moulting its skin. A table is given showing the many physiological functions of an Anopheline larva which may be disturbed by the action of an oil, and the manner in which some of the larvae may die.

After external contact alone between oil and a larva's body any of the following results may be seen. First, oil may adhere to the larva's hairs and interfere with the insect's normal position of balance ; such a larva may drown by sticking upside down at the surface though it has air in both tracheae. Secondly, the normal movements of the larva's feeding brushes may be obstructed by adherent oil globules, so that some larvae are unable to feed and may die of starvation ; others may succeed in freeing their brushes either before or as a result of moulting their skins. Thirdly, oil may poison the larva from outside, without any entering its tracheae.

Certain oils are directly poisonous to a mosquito larva, appearing to act on its muscular tissues, causing convulsions and then paralysis. All the poisons examined, whether volatile or not, were found to be soluble in water and able to penetrate the outer cuticle of a larva's body.

The process of refining kerosenes for use as smokeless fuel is shown to remove from them at least some of the substances which make untreated kerosenes highly toxic to Anopheline larvae. The necessity therefore is to know that a kerosene is toxic, before adding any to an anti-malarial mixture with the intention of raising its efficiency.

The ability of oil to enter the tracheal tubes of a mosquito larva is discussed in the light of observations, recorded in this paper, that the oil/air meniscus in the tracheae of living larvae, partly filled with certain oils, is seen to be convex towards the air. This shape of meniscus is not compatible with the view that oil simply flows along the tracheae by capillary attraction alone ; there must be some force either pushing or sucking the oil in. I have drawn a comparison between the entry of water into the xylem vessels of submerged leaves of land plants and the entry of oil into the tracheal system of living mosquito larvae. And the result of such a comparison is to suggest that, when an oil film blocks for a moment the tracheal spiracles of a larva, the removal of oxygen by respiration from the intra-tracheal air is sufficiently fast to lower the gas pressure within the tracheae ; this causes some oil to be sucked into the tracheae to replace the oxygen. The more rapid the removal of oxygen from the tracheae, the more oil will enter them if the spiracles touch an oil film.

The reason why oil enters the tracheae while water does not is also discussed ; the reason is thought to be the instability of a film of water in the region of the spiracles. In this connection it may be noticed that oil is very commonly seen to enter the tracheae as a direct result of the larva smearing a film of oil over the spiracles, in an attempt to remove an irritant from that region. If the oil is not irritant, no film is accidentally smeared over the spiracles, and oil may then not enter the tracheae until much later.

No larva, either Culicine or Anopheline, in which both tracheae were quite full of any oil has been seen to moult or pupate. Some larvae, however, have been seen in which oil had entered and filled only part of one or of both tracheae. The fate of these " partly oiled " larvae has shown the relative importance of suffocation, poisoning and the obstruction of moulting or pupating. The presence of oil in one trachea only may not prevent the larva from moulting, and the tracheae of the next instar larva have always been found to contain only air ; but oil even only in the tips of *both* tracheae of a larva seriously interferes with moulting and the insect usually dies. Oil in one or both tracheae appears to obstruct the process of pupating more than that of moulting.

The heart is one of the muscles of a larva which may be paralysed by poisons present in certain oils. One part of the heart muscle may be reached and paralysed before another, and many abnormalities of rhythm may be seen before the heart finally ceases to beat. With some at least of the poisonous oils the heart stops in systole. The poisons may reach the heart either through the external cuticle or in certain circumstances through the lining of the tracheae.

The lining of the tracheae of Anopheline larvae appears to be of a waxy material. In experiments where oils containing powerful water-soluble toxins enter the tracheae, the poisons will paralyse the heart muscle in a few minutes if the oil is a fat-solvent ; but if the oil is not a fat-solvent, the larva's heart may still be pulsating 24 hours later. On the other hand a fat-solvent oil which does not contain much water-soluble poison may remain in the tracheae for four hours or more without paralysing the heart muscle.

The effect of oil was studied on a variety of micro-organisms, which form part of a larva's food supply. Contact with certain oil films or emulsions was poisonous to all these micro-organisms, which could be watched being killed, sometimes after a contact of only a few minutes. Yet these same organisms were able to live and multiply under complete surface films of other oils. The oils which killed these micro-organisms were the same as poisoned mosquito larvae.

Some other physical and chemical differences between oils and their effects on larvae are discussed ; these include colour, volatility and smell, spread, " stickiness " and viscosity, and " capillary speed."

A table of experimental results is given, which shows that a difference between two oils in the width of their initial spread on water represents to a larva in that water a difference in its chances of being oiled. The wider the initial spread of an oil, especially on running water where exposure may only be for a few minutes, the greater will be the chance of a larva coming into some contact with the oil. It is where there is a minimum chance of contact that maximum toxicity is of especial importance.

In the section dealing with the entry of oil into the tracheae, I have suggested that the flaps over the tracheal openings are normally held closed by a relatively weak spring, which is easily overcome by the tension forces at the surface of water. And it appeared in certain experiments where oil was used that these flaps might also be opened by the even weaker tension forces at the interface between an oil and water. As explained in another section, the tension at any oil/water interface is usually smaller (sometimes much smaller) than at the water/air interface. This oil/water interfacial tension may be so small in an oil which spreads very widely on water, that the tracheal flaps are not pulled open by it, and they reach the oil/air surface before being opened. In such a case no oil will enter the tracheae. This may be the explanation for a well-established practical rule of anti-malarial oiling, which is that the film of some oils may spread so widely that it ceases to kill mosquito larvae ; and that therefore one should not strive to attain an oil which spreads to a mono-molecular film.

It will be for the future to decide by experiment what interfacial tensions are required to open the tracheal flaps and ensure the certainty of oil being drawn into the tracheae.

It would appear that oil in the form of an emulsion may have both advantages and disadvantages over oil applied as a surface film. The advantages are seen when a toxic oil is applied in very small quantities as an emulsion to stretches of shallow standing water. Here the poisons, being water-soluble, have a chance of acting on the larvae, their food supply and their vegetable shelters, for a longer time than if the water were flowing. In flowing water an emulsion, even of a toxic oil, has two disadvantages. First, much longer time is required by an oil as an emulsion to enter the tracheae than by the same oil as a surface film ; secondly, it was found that the exposure of an Anopheline larva, even for as long as half-an-hour, to toxic emulsions at field strength was not always sufficient to prevent it from moulting.

The anti-malarial aspects of these differences between oils has been reviewed, and the possibility is suggested of using such differences to suit particular local problems of mosquito control. An example is given where an examination of local oils by the technique described in this paper made possible a reduction of 20 per cent. in the cost of an anti-malarial mixture, while possibly raising its efficiency.

The time available in which to kill mosquito larvae is the time until they next moult their skins. If, before this happens, enough oil enters their tracheae to obstruct moulting or to poison or suffocate them, or if their skeletal muscles are paralysed even by a momentary contact with oil, or if their feeding brushes are matted or their food supply poisoned so that they starve to death, then the oil mixture and the method of applying it have been successful.

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THE PTINIDAE OF ECONOMIC IMPORTANCE.

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Introduction.

The work which has resulted in the following paper has been carried out in the Department of Entomology of the British Museum (Natural History), at the request of Professor J. W. Munro and on behalf of the Pest Infestation Laboratory of the Department of Scientific and Industrial Research. The critical material used has been mainly that already available in the British Museum, but it has been partly supplemented from Professor Munro's resources.

Altogether 21 species of Ptinidae have been recorded as pests, most of these causing damage to stored products of various kinds. An attempt is made here to illustrate and sufficiently to describe these species so that any of them can be quickly and accurately identified by those concerned with their control. Owing to the fact that many of the economic species in the genus *Ptinus* are very closely related to each other and moreover frequently exhibit a noticeable degree of sexual dimorphism, it has not been possible to construct a key which can be used with only the aid of a hand lens. However, no difficulties should be encountered in the key if a binocular microscope is used; and it is so made that it is not necessary for those using it to determine the sex of their specimens.

Under the headings of the species will be found brief summaries of their distribution, habits, and the more important literature relating thereto. Three British species of no economic importance, *Ptinus palliatus*, Perris, *P. lichenum*, Marsham, and *P. sexpunctatus*, Panzer, are included so that embodied in this paper is a revision of all the British species of the family Ptinidae. The following Ptinids of economic importance have not yet been recorded from Great Britain: *Mezium americanum*, Lap., *Gibbium boieldieui*, Levrat, *Sphaericus gibboides*, Boie., *Ptinus japonicus*, Reitter, *P. raptor*, Sturm, *P. rufipes*, Oliv., *P. bicinctus*, Sturm, and *P. villiger*, Reitter.

Drawings of the whole insects and of the pronotum were done by Mr. A. Smith. The genitalia and legs were drawn by me with the aid of a camera lucida; and lines next to figures refer to a length of 0·20 mm. The species were described for the most part under a magnification of × 75.

Acknowledgments.

I should like to thank Professor Munro for giving me the opportunity of undertaking this work, and the Trustees of the British Museum for allowing me to accept it. My thanks are also due to Mr. N. D. Riley and Dr. O. W. Richards for their interest in the course of this work and to the D.S. I. R. for rendering it possible to include the drawings by Mr. A. Smith.

A Key to the Ptinidae *of Economic Importance.*

1. Elytra widely embracing the abdomen and about three times as broad as sternum of abdomen. Abdomen with four or five visible sternites; when there are five visible sternites the third is only slightly longer than fourth..................2

Elytra not widely embracing abdomen and less than twice as broad as sternum of abdomen. Abdomen always with five visible sternites and with third twice as long as fourth..5

2. Head, pronotum, and base of elytra densely hairy. Abdomen with five visible sternites. Hind leg with trochanter less than a third as long as femur.........3

Head, pronotum, and elytra glabrous or nearly so. Abdomen with only four visible sternites, the first being concealed by metasternum. Hind leg with trochanter more than half as long as femur...4

3. Pronotum with tomentum so arranged that it appears to have a broad, shallow median sulcus and a broad, feeble gibbosity on each side on basal half (fig. 1). Elytra with basal tomentose collar entire on each side (fig. 1)... *Mezium affine*, Boie.

Pronotum with tomentum so arranged that it appears to have a broad, very deep, median sulcus and a broad, very prominent gibbosity on each side on basal half (fig. 2). Elytra with basal tomentose collar deeply interrupted on each side (fig. 2)..*Mezium americanum*, Lap.

4. Head below eyes with numerous narrow but prominent, subparallel ridges which extend to anterior margin of pronotum......*Gibbium psylloides*, Czenp.

Head below eyes smooth or with only a few feeble ridges which do not extend to anterior margin of pronotum........................*Gibbium boieldieui*, Levrat

5. Elytra smooth or confusedly punctate, never with punctures arranged in parallel rows...*Sphaericus gibboides*, Boie.

Elytra always punctate and with punctures arranged in parallel strial rows...6

6. Breadth of elevated part of head between antennal bases equal to half or more than half of length of first antennal segment...............................7

Breadth of elevated part of head between antennal bases equal to less than a fourth of length of first antennal segment..9

7. Elytra with striae deep and strial punctures coarse and distinctly visible, not concealed by dense hairs..........................*Tipnus unicolor*, Piller & Mitt.

Elytra with striae very shallow or absent and strial punctures fine and completely concealed by dense hairs...8

8. Hairs of dorsal surface uniformly golden. Scutellum large, distinct, and visible from above..*Niptus hololeucus*, Fald.

Hairs of dorsal surface frequently black or dark brown. Scutellum very reduced and not visible from above..............*Trigonogenius globulus*, Sol.

9. Scutellum small, indistinct, and almost vertical. Hind trochanter attaining margin of elytra...*Eurostus hilleri*, Reitt.

Scutellum large, very distinct, and lying in same plane as elytra. Hind trochanter not attaining margin of elytra..10

10. Pronotum near base on each side of middle with a prominent cushion of fine, golden tomentum and at anterior end of each cushion with a broad and very high gibbosity..11

Pronotum without a prominent cushion of tomentum (*P. fur* has a moderately low, hairy or subtomentose cushion on each side of middle) and without a broad and high gibbosity on each side..12

11. Head with white and golden-testaceous hairs. Pronotum with tomentose cushion on each side slightly more than one and a half to nearly twice as long as broad. Elytra with erect hairs of intervals long (frequently four times as long as discal strial punctures) and very unequal, some hairs on odd intervals being more than twice as long as hairs on even intervals. Male genitalia with right paramere shorter than left. Female with punctures of metasternal disk much broader than facets of eyes......*Ptinus japonicus*, Reitt.

Head with only golden-testaceous hairs. Pronotum with tomentose cushion on each side not or only very slightly longer than broad. Elytra with erect hairs on intervals short (seldom twice as long as discal strial punctures) and subequal. Male genitalia with right and left parameres similar. Female with punctures of metasternal disk not broader than facets of eyes............ *Ptinus raptor*, Sturm

12. All tarsi with apex of fourth segment broadly dilated and feebly lobed (figs. 18, 22) 13

All tarsi with apex of fourth segment (fig. 32) narrow and not lobed (*P. lichenum* has apex of fourth tarsal segment feebly dilated, but this species may be distinguished from all others dealt with here by having flat, obovate, white scales on pronotum) 14

13. Pronotum with numerous white hairs. Coarse punctures of metasternum behind middle coxae umbilicate (fig. 19). Female with numerous punctures on middle of first and second abdominal sternites which are distinctly coarser than facets of eyes; middle of fourth abdominal sternite without a setose tubercle. Male with numerous irregular patches of white hairs on elytra; genitalia with parameres only feebly curved inwards at apex (fig. 16)............ *Ptinus palliatus*, Perris

Pronotum without white hairs. Coarse punctures of metasternum behind middle coxae normal. Female with punctures of middle region of first and second abdominal sternites never as coarse as facets of eyes; middle of fourth abdominal sternite with a setose tubercle. Male with elytra more or less uniformly clothed with grey or brownish-testaceous hairs; genitalia with parameres strongly curved inwards at apex (fig. 24)........................ *Ptinus rufipes*, Oliv.

14. Pronotum with white scales or hairs..15

Pronotum without white scales or hairs..16

15. Pronotum with white hairs obovate, flat, and scale-like; on basal half with a median patch of these hairs. Each elytron without a dense patch of golden-brown hairs on basal fourth. Sides of metasternum with punctures never more than one and a half times as coarse as facets of eyes........................ *Ptinus lichenum*, Marsham

Pronotum with white hairs long and very slender; on basal half without a median patch of white hairs. Each elytron with a dense patch of golden-brown hairs on basal fourth. Sides of metasternum with punctures frequently three times as coarse as facets of eyes........................*Ptinus exulans*, Er.

16. Middle of head behind base of antennae with a patch of dense, white hairs. Elytra with setae of discal strial punctures each shorter than its respective puncture. Male genitalia, when seen from dorsal view, with median lobe extending considerably beyond apices of parameres (fig. 33)...................... *Ptinus sexpunctatus*, Panz.

Head without white hairs. Elytra with setae of discal strial punctures always longer than punctures. Male genitalia, when seen from dorsal view, with median lobe not or only very slightly extending beyond apices of both parameres 17

17. Elytra without white scales or hairs..18

Elytra with white scales or hairs (in some specimens, particularly males, there are only a few white hairs)..20

18. Middle of pronotal disk punctate. Elytral intervals with dense, fine, short, recumbent hairs and each interval with a median row of long, erect to suberect hairs. Male genitalia with median lobe abruptly and strongly broadened at basal two-fifths.. *Ptinus tectus*, Boie.

Middle of pronotal disk granulate. Elytral intervals without short, recumbent hairs ; each with only a median row of long, suberect to erect hairs. Male genitalia with median lobe evenly broadened towards base.....................19

19. Female with erect hairs of elytral intervals fine and on apical half distinctly unequal, some being nearly twice as long as others ; intervals near base of elytra with or without a patch of moderately dense, testaceous, recumbent hairs. Punctures of middle of metasternal disk and middle of first abdominal sternite round to oval. Male with punctures of second elytral stria on apical half separated longitudinally by usually less than one to one diameter......... *Ptinus hirtellus*, Sturm

Female with erect hairs of elytral intervals coarse and on apical half all nearly equal in length ; intervals near base of elytra never with a patch of recumbent hairs. Punctures of middle of metasternal disk and middle of first abdominal sternite two to three times as long as broad. Male with punctures of second elytral stria on apical half separated longitudinally usually by more than one to two diameters.. *Ptinus latro*, F.

20. Disk of pronotum on each side with a feebly oblique, longitudinal, hairy or subtomentose cushion (figs. 45, 46)................................ *Ptinus fur*, L.

Disk of pronotum with the hairs more or less evenly distributed, never forming a longitudinal subtomentose cushion on each side................................21

21. Middle of second abdominal sternite with round to feebly oval punctures. Male with apical spur of middle and hind tibia very long and strongly curved ; genitalia with left and right parameres similar...... *Ptinus pusillus*, Sturm

Middle of second abdominal sternite with oval to elongate punctures which are often two or three times as long as broad. Male with apical spur of middle and hind tibia short and straight ; genitalia with right and left parameres differently setose..22

22. Erect hairs of elytral intervals subequal in length..................................23

Erect hairs of elytral intervals very unequal in length, intervals 1, 3, 5, and 7 with numerous hairs which are about twice as long as those of even intervals 24

23. Middle of pronotum on basal two-fifths with a moderately prominent gibbosity (fig. 56). Middle of elytral disk with strial punctures about as broad as intervals... *Ptinus subpilosus*, Sturm, ♂

Middle of pronotum without a gibbosity. Middle of elytral disk with strial punctures one-half to three-fifths as broad as intervals.......................... *Ptinus bicinctus*, Sturm

24. Elytra subparallel. Fourth tarsal segment distinctly shorter than third......... *Ptinus villiger*, Reitt., ♂

Elytra obovate. Fourth tarsal segment as long as or only very slightly shorter than third..25

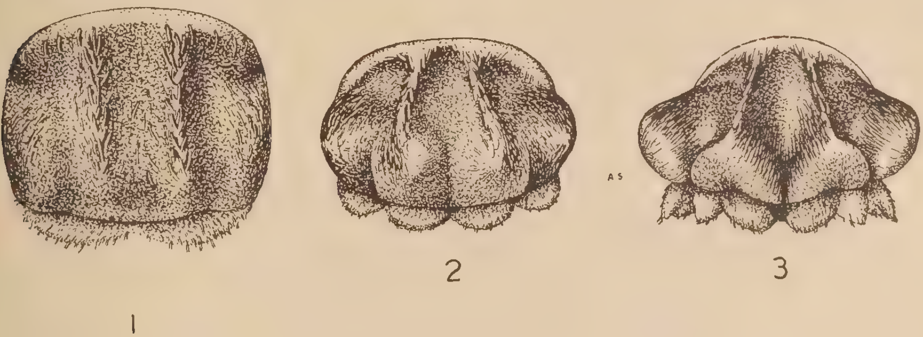
25. Elytra with strial punctures of middle of disk one-half to two-thirds as broad as intervals.. *Ptinus villiger*, Reitt., ♀

Elytra with strial punctures of middle of disk as broad as intervals.............. *Ptinus subpilosus*, Sturm, ♀

Mezium affine, Boieldieu (fig. 1).

Mezium affine, Boie., Ann. Soc. ent. Fr. **4,** 1856, p. 674.

♂. Length, 2·3–3·5 mm. ; breadth, 1·3–1·9 mm. Broadly oval with elytra very strongly convex and inflated posteriorly ; cuticle shining and dark reddish-brown to nearly black. *Head* and antennae very densely clothed with recumbent to suberect, golden-testaceous scales and hairs. Eyes strongly convex, nearly round, and about half as broad as second antennal segment. Surface of front of head (when hairs are rubbed off) densely often confluently granulate and rugose, the granules being about twice as coarse as facets of eyes. *Pronotum* with shape as shown in fig. 1. Densely clothed like head but with hairs usually longer and more parallel, seldom scale-like. Surface beneath vestiture sculptured similarly to head. *Elytra* with a narrow basal collar clothed like head, this collar being only partly interrupted at middle (fig. 1) ; near collar on each side of suture with a few stout, erect hairs which are about as long as second antennal segment ; on extreme apical region with numerous short, very stout, erect hairs ; surface of elytra elsewhere polished and nearly impunctate. *Legs* and *sternites* clothed like antennae but with numerous stout, moderately long, erect hairs. Metasternum and abdominal sternites densely, moderately coarsely, rugosely punctate.



Figs. 1–3. Dorsal view of pronotum and base of elytra of (1) *Mezium affine,* Boie. ; (2) *M. americanum,* Lap. ; (3) *M. sulcatum,* F.

♀. Externally similar to ♂.

Distribution. Europe, North Africa.

Habits. It is found in houses, warehouses, and granaries. It has been found in seeds and various kinds of decaying animal and vegetable refuse (Fowler, 1890) and feeding on dead insects and also on the lining of an opera hat (Patton, 1931).

Mezium americanum, Laporte (figs. 2, 4).

Gibbium americanum, Lap., in Brullé, N. H. Anim. Artic. (Coleopt.) **1,** 1840, p. 297.

♂. Length, 1·5–3·5 mm. ; breadth, 0·98–1·8 mm. Similar to *M. affine* except in the following particulars : (1) median sulcus of pronotum deeper and broadening posteriorly instead of subparallel-sided ; (2) pronotum with sublateral gibbosity (formed by hairs) on each side much more prominent (*cf.* figs. 1 and 2) ; and (3) basal collar of elytra partly interrupted on each side instead of entire (*cf.* figs. 1 and 2). Elytra usually without hairs except for a few stout, long, erect ones on each side of suture near base ; unrubbed specimens with similar hairs sparsely distributed over elytra except on sides, these hairs becoming progressively shorter posteriorly.

♀. Externally similar to ♂.

Distribution. Cosmopolitan.

Comparative notes. This species is also close to *M. sulcatum* (F., 1781) with which it is sometimes confused in collections, but may be immediately distinguished by having the elytral collar partly interrupted only once instead of twice on each side (*cf.* figs. 2 and 3).

Habits. It occurs in dwellings in dried animal products (Cotton & Good, 1937), in warehouses (Brown, 1940), and in mills (Back & Cotton, 1938). It has been found breeding in tobacco seed (Runner, 1919) and is known to infest cayenne pepper, opium, grain, etc. (Cotton & Good, 1937).

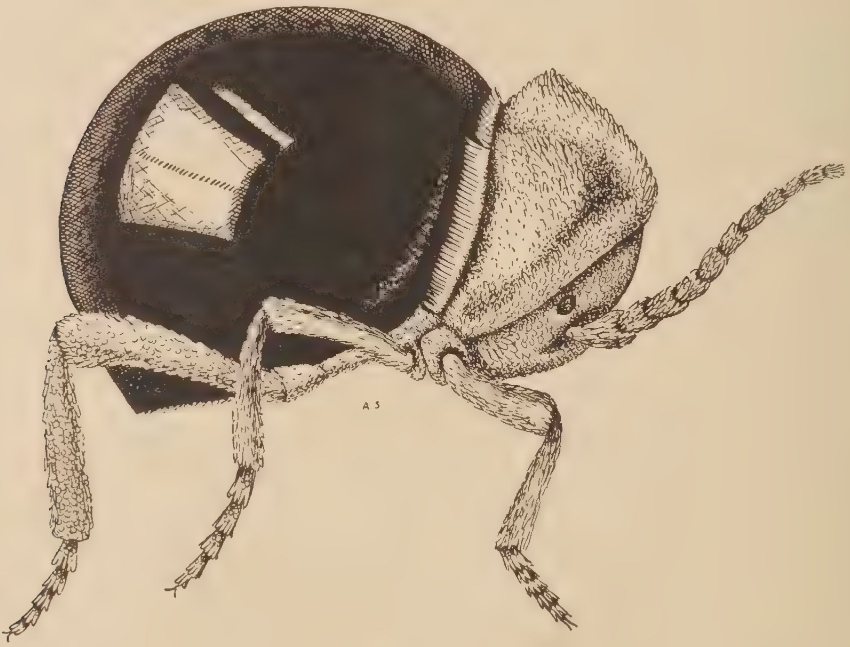


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Fig. 4. *Mezium americanum*, Lap.

Gibbium psylloides, Czenpinski (fig. 5).

Scotias psylloides, Czenp., Diss. zool.-med., 1778, p. 51.
Ptinus scotias, F., Spec. Ins. **1,** 1781, p. 74.

♂. Length, 1·7–3·2 mm.; breadth, 1·15–2·24 mm. Broadly oval, elytra very strongly convex and also inflated posteriorly; cuticle shining, dark brownish-red to nearly black. *Head* with a deep, moderately narrow, median longitudinal impression on front; surface behind and below small, nearly round, flat eye on each side with about fifteen to twenty fine, more or less acute, subparallel ridges which extend to anterior margin of pronotum; surface elsewhere with a few fine punctures; anterior part of frons and genae with numerous recumbent, testaceous setae, the surface elsewhere being glabrous or nearly so. Antennae, clypeus, and labrum very densely clothed with recumbent, golden-testaceous hairs. *Pronotum* glabrous, with only a few microscopic punctures, evenly convex, and with shape as shown in fig. 5. *Elytra* glabrous except for a few very fine setae at extreme apex, polished, and nearly impunctate. *Scutellum* not externally visible. *Underside* densely clothed with moderately long, erect, golden-testaceous hairs. Middle of metasternal disk with a long, erect, compact brush of very fine, testaceous hairs arising from a large, round, shallow puncture. Legs very densely clothed with recumbent to suberect, fine or coarse, golden-testaceous hairs.

♀. Differs from ♂ in not having a large round puncture or an erect brush of compact hairs on middle of metasternal disk.

Distribution. Cosmopolitan.

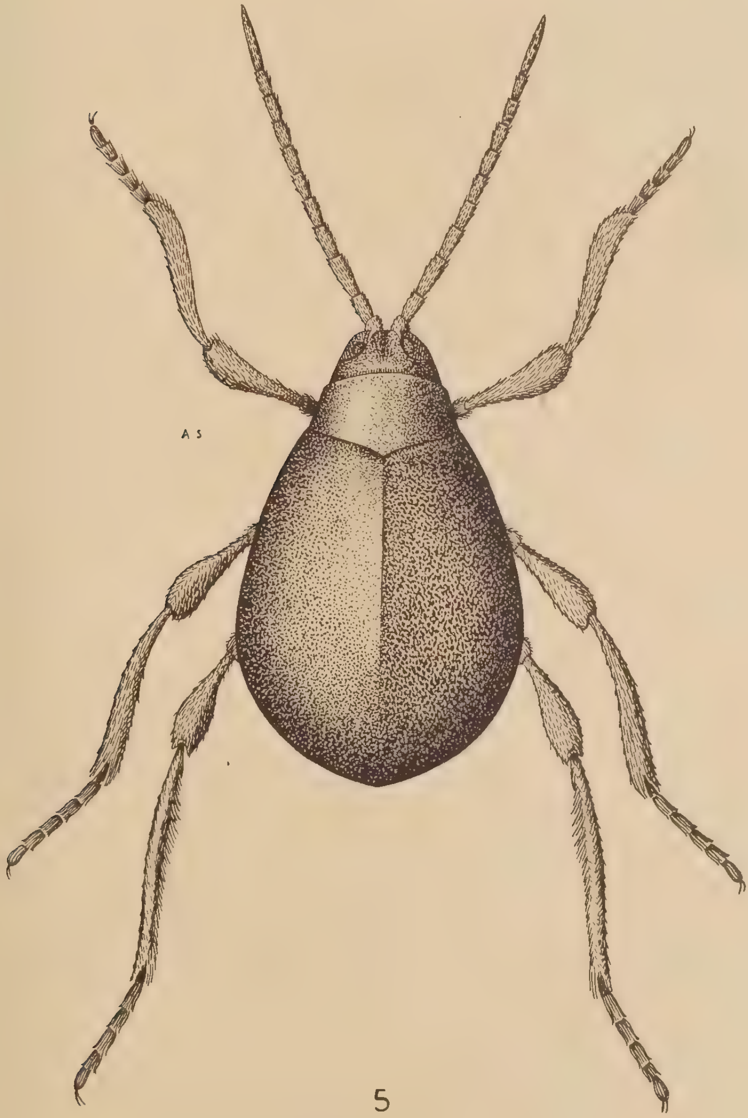

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Fig. 5. *Gibbium psylloides*, Czenp.

Habits. It is frequently found in houses, hotels, warehouses, mills, granaries, bakeries, latrines, etc. It has been recorded feeding in cayenne pepper (Lucas, 1884), stored seeds (Kunhikannan, 1919), wheat bran (Lyle, 1938), stale bread in bakery (Chittenden, 1911), and decaying animal and vegetable refuse (Fowler, 1890). Cotton & Good (1937) record it feeding on stored wheat, cereals, opium cakes, paste, hay, and animal matter. Kemper (1938) records it attacking a rubber sponge bath-mat, woollen material, towels, leather, paste, and tallow in a factory. The early stages are described by Fletcher & Ghosh (1920) and Kemper (1939).

Gibbium boieldieui, Levrat.

Gibbium boieldieui, Levrat, Ann. Soc. Linn. Lyon **4,** 1857, p. 419.

♂. Length, 1·9–2·3 mm.; breadth, 1·2–1·4 mm. Broadly oval, elytra very strongly convex and inflated posteriorly; cuticle dark brownish-red to nearly black. Externally very similar to *G. psylloides* but may be distinguished from it by having the head below eyes smooth or with only a few feeble ridges most of which do not extend to anterior margin of pronotum.

♀. Differs from ♂ in not having a large, round puncture or an erect brush of compact hairs on middle of metasternal disk.

Distribution. Europe, Persia, Russia, Malay Archipelago.

Habits. It is found in houses feeding on bread, cheese, and moulds (Zacher, 1933). Cotton & Good (1937) record it feeding on pastry, cork, and insect collections. The early stages are described by Obrastov (1928) and Zacher (1933).

Sphaericus gibboides, Boieldieu.

Trigonogenius gibboides, Boie., Bull. Soc. ent. Fr. (3) **2,** 1854, p. lxxxiv.

♂. Length, 1·6–2·8 mm.; breadth, 1·2–2·0 mm. Broadly oval; cuticle opaque, dark rufo-piceous with elytra, antennae, and legs slightly paler. *Head* densely clothed with short, recumbent, golden-testaceous hairs. Surface with low, dense granules which are slightly finer than facets of eyes; on middle of front with granules slightly finer and often separated by one diameter. Eyes strongly convex, oval, and about two-thirds as broad as first antennal segment. *Pronotum* evenly convex, sides feebly arcuate, nearly parallel, and not constricted near base. Surface with very dense to contiguous granules which are one and a half to twice as coarse as facets of eyes; densely clothed with short, flat, obovate, recumbent, greyish-testaceous hairs and also with numerous slightly longer, stout, nearly parallel, slightly more golden hairs. *Elytra* clothed like pronotum but with hairs and scales (which are easily rubbed off) slightly finer and shorter, these scales and hairs becoming slightly shorter as apex is approached. Surface densely, microscopically punctate and with low granules which are slightly finer than facets of eyes and are usually separated by two to four diameters. *Scutellum* much reduced, not visible from above. *Metasternum* without a median longitudinal line; disk flat and with very deep, nearly round, very coarse (about half as broad as an eye) punctures which are usually separated by one-third a diameter. Abdominal sternites with deep, round to oval punctures which are about one and a half times as coarse as facets of eyes and are separated by one-half to one diameter; towards apex these punctures become finer and sparser, and on fourth and fifth sternites they are very shallow, sparse, and indistinct.

♀. Externally similar to ♂.

Distribution. South Europe, North Africa, California.

Habits. It has been recorded as a herbarium pest and living in red pepper (Fall, 1905).

Tipnus unicolor, Piller & Mitterpacher (fig. 6).

Ptinus unicolor, Piller & Mitt., Iter Poseg., 1783, p. 67.
Ptinus crenatus, F., Ent. Syst. **1** (1), 1792, p. 240.

♂. Length, 1·8–3·0 mm.; breadth, 1·0–1·6 mm. Broad, obovate; cuticle shining, colour rufo-piceous. *Head* with fine, moderately dense, recumbent to suberect, brownish-testaceous hairs which are a fourth to a half as long as third antennal segment; surface with very dense to contiguous, low granules which are slightly finer than facets of eyes. Antennae two-thirds as long as body; middle segments about a fourth longer than broad. Eyes oval, moderately convex, and nearly as broad as first antennal segment. *Pronotum* with shape and impressions as shown in fig. 6. Surface sculptured like head but with granules, particularly near base, often slightly coarser than facets of eyes; with a single basal marginal row of coarse, deep punctures which are usually separated by one diameter or less; golden hairs arising from tubercles recumbent to suberect, moderately dense, and one-third to four-fifths as long as third antennal segment. *Elytra* on each interval with a single row of erect, golden hairs which are as long to half again as long as strial punctures; intervals also with numerous moderately sparse, recumbent, golden hairs which are slightly shorter than erect hairs; seta arising from anterior margin of each strial puncture about as long as its respective puncture. Strial punctures

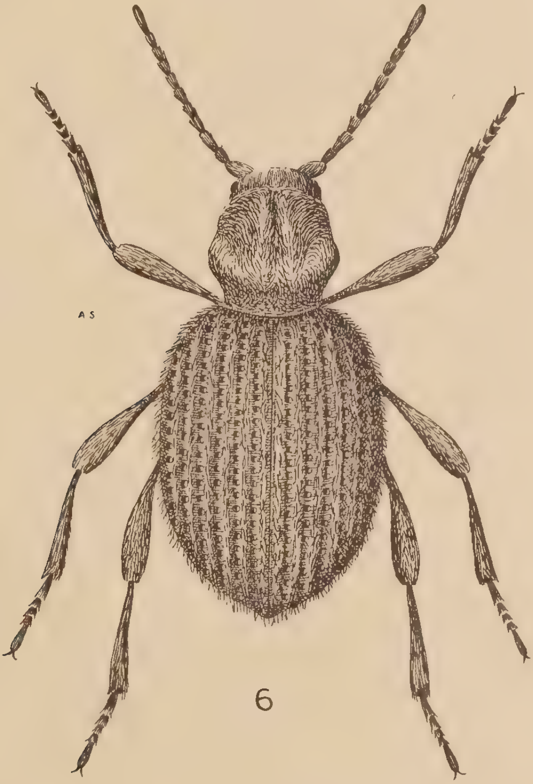

Fig. 6. *Tipnus unicolor*, Piller & Mitt.

on middle of disk very deep, round, one-half to three-fifths as broad as intervals, and separated longitudinally by usually one diameter though occasionally by much less. *Scutellum* reduced, nearly vertical, and scarcely visible from above. *Metasternum* without a median longitudinal line ; disk flat to feebly concave and with round to oval punctures which are as coarse as to one-fourth coarser than facets of eyes and are separated by less than to one diameter ; surface between these punctures with numerous microscopic punctures. Abdomen with middle of first three sternites sculptured like middle of metasternal disk.

♀. Externally similar to ♂.

Distribution. Europe, Transcaucasia, Canada.

Habits. It is found in houses, bakeries, corn shops (Pool, 1906), flour mills (Bedwell, 1906), warehouses (Brown, 1940), stables, etc. Zacher (1927) has recorded it in moist skins, Cotton & Good (1937) on grain and in bread stores, and Fowler (1890) in old wood and in birds' nests. In the British Museum there are specimens taken in the nest of a house martin.

Niptus hololeucus, Faldermann (fig. 7).

Ptinus hololeucus, Fald., N. Mém. Soc. Imp. Nat. Moscou **4,** 1835, p. 214, t. 7, f. 6.

♂. Length, 3·0–4·5 mm. ; breadth, 1·5–2·6 mm. Broadly oval, strongly convex ; cuticle reddish-brown, shining. Easily recognized by the golden vestiture which completely conceals cuticle everywhere on body and on antennae and legs, the vestiture being composed of very dense, moderately short, recumbent hairs which are finely divided at apices and longer, erect, slightly darker, and much sparser hairs which are often evenly pointed. *Head* with a broad, shallow, median impression on front ; surface with dense to confluent punctures which are slightly finer than facets of eyes ; between these punctures with numerous microscopic punctures. *Pronotum* with shape as shown in fig. 7 ; disk evenly convex and surface punctate and rugose like front of head ; surface of basal fifth much more coarsely rugose and with granules which are about twice as coarse as facets of eyes. *Elytra* with striae not or only scarcely noticeably impressed ; strial punctures on middle of disk deep to very shallow, round, a fifth to a third as broad as intervals, and separated longitudinally by one to four diameters ; in each puncture there is an erect hair which is about one-half as long as erect hairs of intervals. *Scutellum* moderately large, distinctly visible from above, and on same plane as adjacent parts of elytra. *Metasternum* without a median longitudinal line ; disk flat and with shallow, round punctures which are slightly finer than facets of eyes and are separated by two to five diameters ; surface between these punctures with microscopic punctures which are usually separated by one to three diameters. Abdomen with middle region of first three sternites punctate like metasternal disk. Legs with femora strongly clavate, each rather abruptly broadened at apical half.

♀. Externally similar to ♂.

Distribution. Nearly cosmopolitan but absent in tropics.

Habits. It is found in houses, bakeries, flour mills, warehouses, granaries, corn shops, factories, etc. It feeds on a great variety of dried organic materials, *e.g.* dead insects (Braune, 1929) including its own species (Pussard, 1928) ; excreta of rats and mice (Vogel, 1929) ; feathers, brushes, and leather goods (Andres, 1920) ; woollen goods (Zacher, 1922 ; Pussard, 1928) ; bath sponges (Arndt, 1929) ; cotton and linen (Zacher, 1928 b) ; clothing soiled by grease (Braune, 1929) ; silk (Pussard, 1929); books and papers stored for long periods (Marcus, 1929) ; false ceilings (Marcus, 1929) ; bran (Zacher, 1936) ; grain (Tullgren, 1917) ; flour and dry cake crumbs (Pussard, 1928) ; stored seeds (Berkman, 1929) ; bread (Zacher, 1936) ; cacao (Andres, 1920) ; and casein (Patton, 1931).

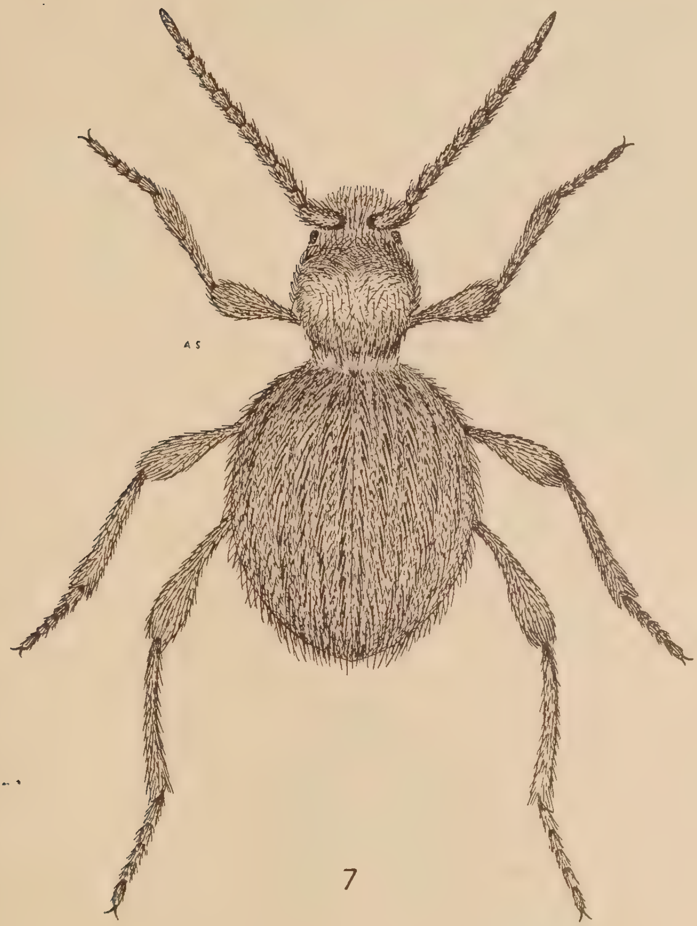

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Fig. 7. *Niptus hololeucus*, Fald.

The biology and control of this species has been dealt with by Boldyrev (1922) ; Geinitz (1928) ; Braune (1928a and b) ; Krauss (1928) ; Pohl (1928) ; Reh (1929) ; Zacher (1929, 1936) ; Pussard (1929) ; Kohler (1930) ; Marcus (1929, 1930) ; Miles (1933) ; and Kemper (1935, 1937).

Trigonogenius globulus, Solier (fig. 8).

Trigonogenius globulum, Solier, in Gay, Hist. Chile **4,** 1849, p. 464, t. 11, f. 7, *a, f.*

♂. Length, 2·0–3·9 mm. ; breadth, 1·2–2·3 mm. Broadly oval ; cuticle shining and dark reddish-brown but everywhere concealed by dense hairs. *Head* very densely clothed with stout, recumbent, greyish-testaceous hairs which are about half as long as third antennal segment and also with a number of suberect to erect, brown bristles which are two to three times longer. Surface of front with shallow punctures which are about two-thirds as coarse as facets of eyes and are separated by less than one to one diameter. Antennae one-half as long as body. Eyes oval, strongly convex, and about as broad as first antennal segment. *Pronotum* with shape and impressions as shown in fig. 8, the longitudinal sulcus and other impressions being almost entirely due to variations in length of hairs. Pronotum with a very dense mat of interlacing hairs and with numerous brown, erect bristles which are as long as combined length of first two or three antennal segments. Surface with low to moderately prominent, very dense, and very large (about half as broad as an eye) tubercles; at sides of disk on anterior fifth also with a few large, oval punctures. *Elytra* with erect hairs of intervals five to ten times as long as discal strial punctures, brown, and very unequal, those of odd intervals often being twice as long as those of even intervals; dense, recumbent hairs of intervals similar to those of head but generally marmorate with darker brown or black; always with a black patch on each side of suture near base and on humeri. Striae not or only scarcely noticeably impressed; strial punctures of middle of disk round to oval, moderately deep, about one-seventh as broad as intervals, and separated longitudinally by one to three diameters. Scutellum not visible from above. *Metasternum* without a median longitudinal line; on posterior fifth of disk with a small median puncture from which arises a moderately short, erect, compact brush of fine hairs; disk feebly convex and surface set with microscopic punctures which are separated by one to three diameters. Abdomen with middle region of first three sternites punctate like metasternal disk. Legs clothed like front of head but with recumbent hairs fine and erect bristles shorter and golden instead of brown; femora broad and not abruptly clavate.

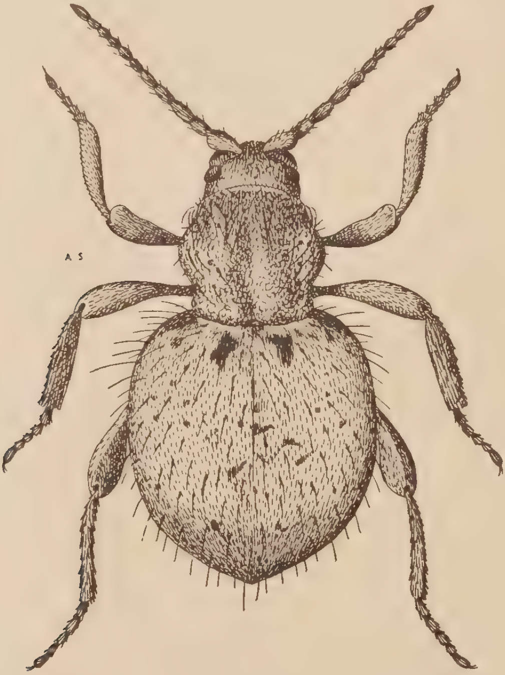

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Fig. 8. *Trigonogenius globulus*, Sol.

♀. May be distinguished from ♂ by its slightly shorter metasternum and absence of median, setiferous puncture on posterior fifth of metasternal disk.

Distribution. Europe, Africa, North and South America, Tasmania.

Habits. It is found in houses, warehouses, granaries, and in cotton, flour, and corn mills. It has been recorded feeding in argol (Scott, 1921), vegetable ivory (*Phytelephas*) (Strong, 1921), caraway seeds (Vappula, 1937), and on dried pears (Richards & Herford, 1930).

Eurostus hilleri, Reitter (fig. 9).

Niptus hilleri, Reitter, Deutsche Ent. Zeit. **21,** 1877, p. 378.
Eurostus alienus, Brown, Canad. Ent. **72,** 1940, p. 119 (*syn. n.*).

♂. Length, 1·9–2·8 mm. ; breadth, 1·0–1·6 mm. Broadly oval ; cuticle dark reddish-brown, shining. *Head* moderately densely clothed with fine, recumbent, golden brown hairs which are about half as long as third antennal segment ; surface of front confluently punctate with round, very shallow punctures which are about half as coarse as facets of eyes ; surface between these coarse punctures with very dense, microscopic ones ; base and sides with numerous low, indistinct granules. Eyes oval, nearly flat, and about as broad as first antennal segment. Antennae two-thirds as long as body. *Pronotum* with shape and impressions as shown in fig. 9.

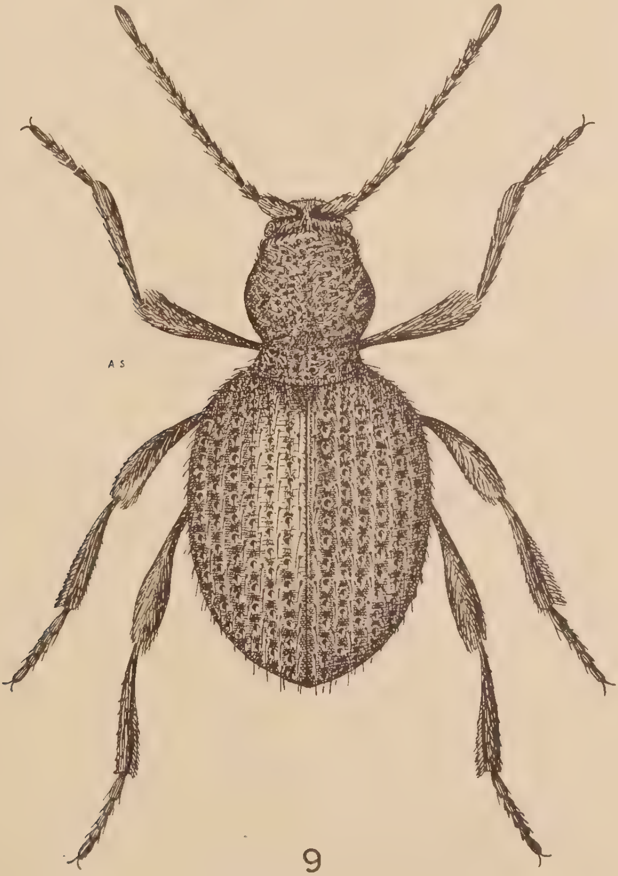

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Fig. 9. *Eurostus hilleri*, Reitter.

Surface of disk with round, shallow punctures which are slightly coarser than facets of eyes and are usually confluent ; surface between coarse punctures densely, microscopically punctate ; on apical fifth with numerous coarser and deeper punctures and on basal fifth with a number of coarse, low granules ; with a single basal marginal row of coarse, deep, and close punctures. Hairs of pronotum moderately sparse, arising from punctures and tubercles, suberect to erect, and frequently as long as third antennal segment. *Elytra* with erect hairs of intervals more or less equal in length and about three times as long as discal strial punctures. Striae not or only very feebly impressed ; strial punctures of middle of disk round to irregularly shaped, moderately deep, a fourth to a third as broad as intervals, and separated longitudinally usually by two to three diameters ; setae of strial punctures suberect and each slightly longer than its respective puncture. *Scutellum* broad but very short and indistinct. *Metasternum* without a median longitudinal line ; disk nearly flat and surface with shallow punctures which are about as coarse as facets of eyes or slightly finer and are usually separated by two diameters ; surface between coarse punctures with numerous microscopic punctures. Abdomen with middle region of first three sternites punctate like metasternal disk but with coarse punctures often slightly larger, more oval, and usually separated by one diameter.

♀. Easily distinguished from ♂ by brush of long, erect hairs arising from a large, shallow, oval puncture on each side of middle apical region of fifth abdominal sternite.

Distribution. Japan, Great Britain, Canada.

Habits. It is found in granaries and warehouses. This species has only recently become a pest. In 1936 it was taken in warehouses in Canada (Brown, 1940), in 1939 it was found to be widely distributed in Scotland (Howe, 1940), and this year (1940) has been taken in warehouses in Liverpool, Gloucester, Hull, Newcastle, Sunderland, South Lincolnshire, and London.

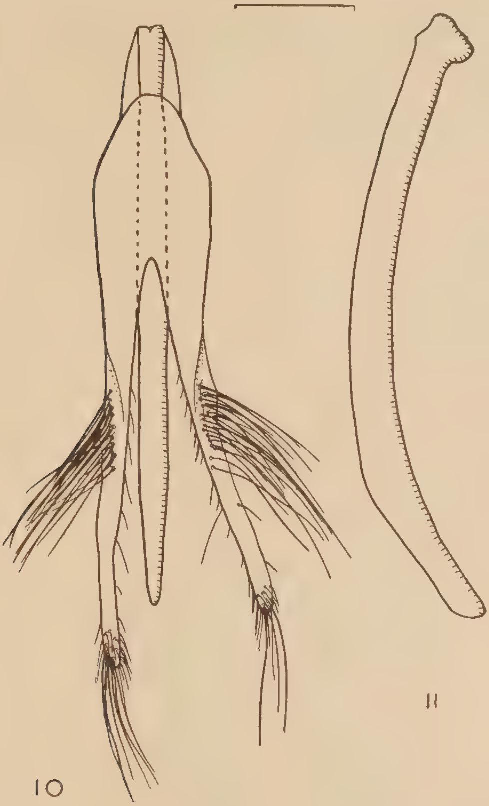
Ptinus japonicus, Reitter (figs. 10–12).

Ptinus japonicus, Reitter, Deutsche Ent. Zeit. **21,** 1877, p. 377.

Ptinus (*Gymnopterus*) *senilis*, Kiesen., Deut. Ent. Zeit. **23,** 1879, p. 317 (*syn. n.*).

I have examined the type of *Ptinus senilis*, which is in the British Museum, and find that it agrees in all particulars with Reitter's description of *P. japonicus*. Kiesenwetter does not compare (*op. cit.*) his new species with *P. japonicus* and furthermore refers *P. senilis* to the subgenus *Gymnopterus*, Muls., when in point of fact it belongs to the subgenus *Cyphoderes*, Muls.

♂. Length, 3·4–4·8 mm. ; breadth, 1·2–2·0 mm. Elongate, subparallel-sided ; cuticle brownish. *Head* densely clothed with long, recumbent, white and golden-testaceous hairs ; golden hairs on each side opposite posterior two-fifths of eye often suberect to erect. Surface with shallow, very dense, usually contiguous punctures which are about half as coarse as facets of eyes. *Pronotum* on each side of middle with a very prominent, parallel-sided cushion of dense, golden-testaceous tomentum which extends from basal fourth to apical two-fifths and is about twice as long as broad (0·43 : 0·22 mm.) ; at anterior end of each tomentose cushion is a broad and high gibbosity which has its posterior face feebly concave ; between posterior two-fifths of tomentose cushions with a moderately low, longitudinal gibbosity. Surface with low tubercles which are slightly finer to slightly coarser than facets of eyes, are separated by one to two diameters, and each gives rise to a long (half to three-fourths as long as third antennal segment), erect to suberect, testaceous seta ; with a single basal marginal row of punctures which are about twice as coarse as facets of eyes and are usually separated by one diameter ; anterior middle fifth of pronotum with numerous similar punctures ; surface on basal and apical region sculptured like head but on middle more lightly so. *Elytra* with numerous long, white, recumbent hairs on intervals behind humeri, on second to tenth on apical fourth, on second



Figs. 10–11. *Ptinus japonicus*, Reitter : (10) dorsal view of male genitalia ; the caudal sutures of the basal piece are not drawn in this and many of the following species as they cannot be seen distinctly ; the setae are approximately correct ; (11) right lateral view of median lobe.

from apical fourth to apex, and sometimes with an occasional white hair on other discal, lateral, or apical intervals. Erect hairs of intervals long (longest hairs three to four times as long as discal strial punctures) and very unequal, some hairs on odd intervals being more than twice as long as hairs of even intervals. Strial punctures on middle of disk deep, subquadrate, as broad as intervals, and separated longitudinally by slightly less than their diameters. *Scutellum* densely clothed with long, suberect, golden-testaceous to nearly white hairs. *Metasternum* with discal punctures usually slightly narrower than facets of eyes, oval to twice as long as broad, and separated by two to three diameters. Abdomen with middle region of first three sternites with punctures which are as broad as those of metasternal disk and are two to five times as long as broad. Tarsi with apex of fourth segment simple, not dilated. *Genitalia* (figs. 10–11) as figured.

♀. May be distinguished from ♂ as follows : (1) tomentose cushions of pronotum (fig. 12) slender, longer, more prominent, and moderately converging posteriorly instead of being nearly parallel ; (2) between tomentose cushions without a gibbosity ; (3) elytra slightly broader and feebly oval instead of nearly parallel ; (4) disk of metasternum shorter, flat instead of moderately convex, with a much shorter median longitudinal line, and with punctures of disk nearly half again as coarse to twice as coarse as facets of eyes, and round to oval, seldom twice as long as broad ; and (5) abdomen with punctures of middle of first three sternites as coarse to one and a half times as coarse as facets of eyes and seldom more than twice as long as broad.

Distribution. Japan : Kobe, Miyanoshita, Sapporo, Niigata, Yokohama, Junsai Lake. China. India : Sikkim. Russia : Amur.

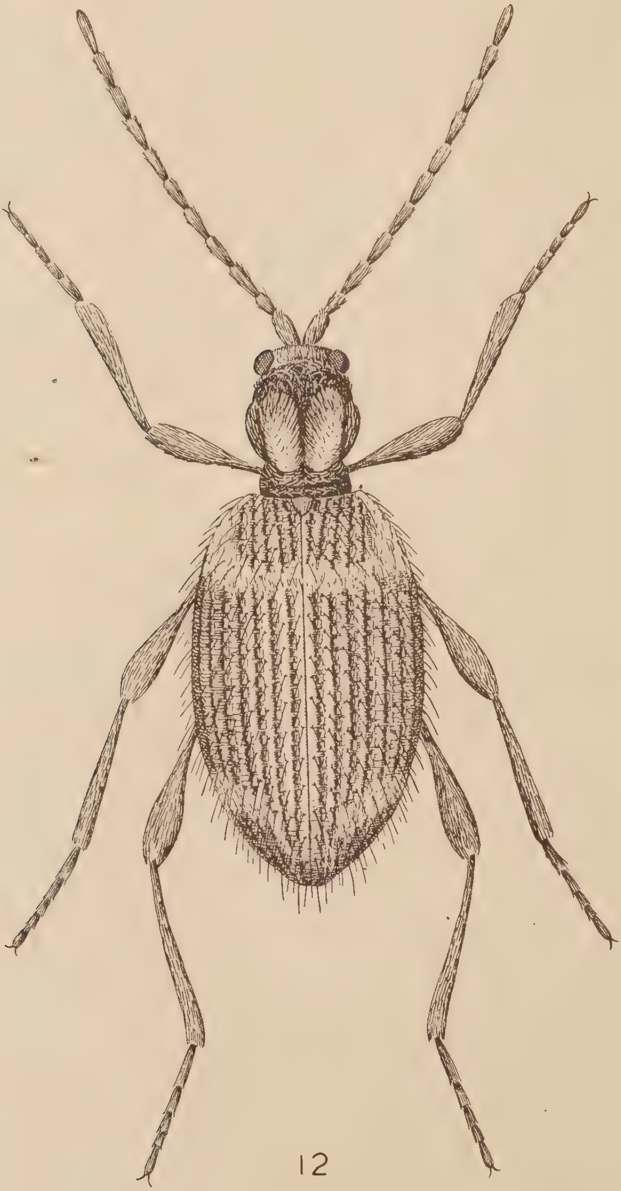


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Fig. 12. *Ptinus japonicus*, Reitter, ♀.

Comparative notes. This is closely related to *P. bidens*, Oliv., 1790, and *P. raptor*, Sturm, 1837. From *P. bidens* it may be distinguished by its much larger size (3·4–4·8 mm. : 2·0–3·3 mm.), less prominent pronotal gibbosity, and simple instead of feebly dilated apex of fourth tarsal segment. From *P. raptor* it may be distinguished as shown in the key given above.

Habits. It has been found damaging flour made of *Amorphophallus koniac* which is used for food in Japan (Tamura, 1939).

Ptinus raptor, Sturm (figs. 13–15).

Ptinus raptor, Sturm, Deutschl. Ins. **12,** 1837, p. 53, t. 250.

♂. Length, 3·0–4·0 mm. ; breadth, 1·4–1·8 mm. Elongate, subparallel-sided ; cuticle brownish-piceous. *Head* moderately densely clothed with long, recumbent, golden-testaceous hairs ; golden hairs on each side opposite posterior two-fifths of eye frequently suberect to erect. Surface densely, microscopically asperate.* *Pronotum* on each side of middle with a very prominent cushion of dense, golden-testaceous tomentum which extends from basal four to apical half and is as long as broad or slightly longer than broad (0·24 : 0·21 mm.) ; at anterior end of each tomentose cushion is a broad and high gibbosity which has its posterior face feebly concave ; between posterior two-fifths of tomentose cushions feebly gibbous. Surface with low tubercles which are slightly finer to slightly coarser than facets of eyes, separated by less than one to two diameters, each giving rise to a long (about two-fifths as long as third antennal segment), suberect to erect, testaceous seta ; with a single basal marginal row of punctures which are about twice as coarse as facets of eyes and usually separated by about one diameter ; anterior middle sixth of pronotum with a number of similar punctures ; surface between granules and punctures on basal fourth and apical sixth densely, microscopically asperate ; surface on most of middle smooth or nearly so. *Elytra* with numerous white, recumbent, obovate (about three times as long as broad) hairs which are about as long as strial punctures and are on intervals behind humeri, on second to tenth on apical fourth, and frequently

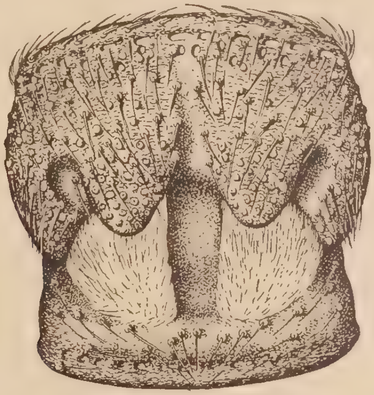

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Fig. 13. *Ptinus raptor*, Sturm, ♀.

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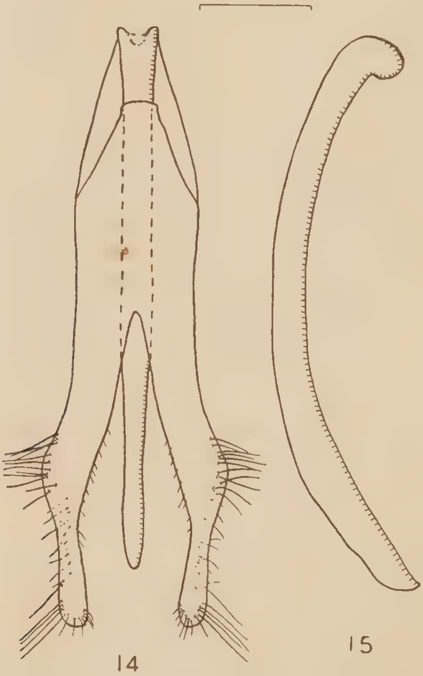
* The term asperate is used in this paper to describe a type of sculpture which consists of fine more or less dense, very shallow, flat-bottomed punctures which are separated by very fine ridges.

on apical intervals. Erect hairs of intervals short (one to one and a half, rarely two, times as long as discal strial punctures) and subequal, some hairs being half again as long as others. Strial punctures on middle of disk deep, subquadrate, as broad as intervals, and separated longitudinally by slightly less than their diameters. *Scutellum* densely clothed with moderately long, suberect, golden-testaceous hairs. *Metasternum* with discal punctures usually distinctly narrower than facets of eyes, two to three times as long as broad, and separated by one to three diameters. Abdomen on middle of first three sternites with punctures which are as broad as those of metasternal disk and two to five times as long as broad. Tarsi with apex of fourth segment simple, not dilated. *Genitalia* (figs. 14–15) as figured.



Figs. 14–15. *Ptinus raptor*, Sturm : (14) dorsal view of ♂ genitalia ; (15) right lateral view of median lobe.

♀. Differs from ♂ as follows : (1) elytra slightly broader and feebly oval instead of parallel ; (2) discal strial punctures of elytra slightly finer, being frequently only three-fifths as broad as intervals ; (3) metasternum shorter, disk flat instead of convex, with a narrower and shorter median longitudinal line, and with shorter, more oval punctures ; and (4) abdomen with punctures of first three sternites as coarse as but slightly shorter than those of male.

Distribution. Europe. Russia : Amur. United States : New York, Maine. Canada. Newfoundland.

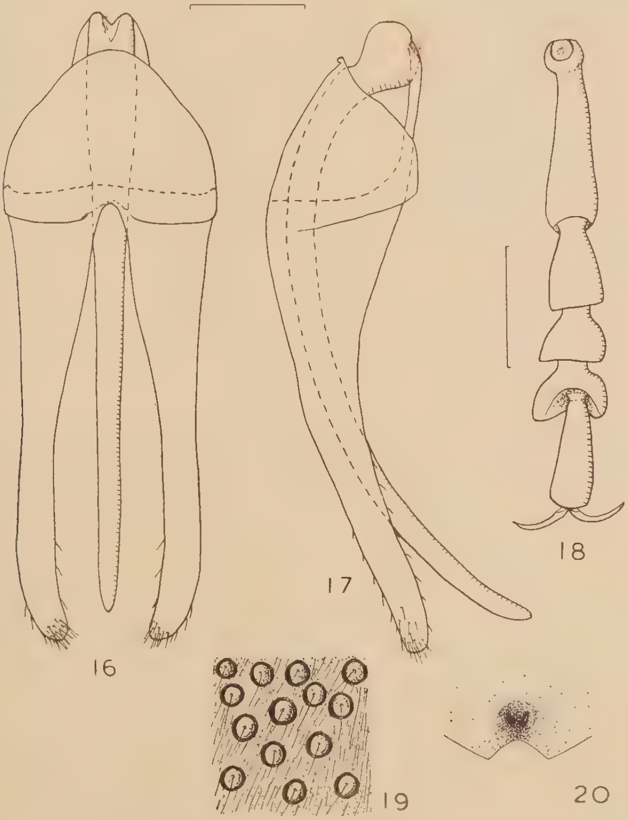
Comparative notes. From *P. bidens*, Oliv., it may be distinguished by its larger size, less prominent pronotal gibbosities and tomentose cushions, subequal instead of very unequal hairs of elytral intervals, and simple instead of feebly dilated apex of fourth tarsal segment. From *P. raptor*, Sturm, it may be distinguished as shown in the key given above. The male genitalia are very close to those of *P. fur*, L., but these two species may be immediately distinguished by the very different structure of the pronotum.

Habits. It has been found damaging stored grain in warehouses in Sweden (Tullgren, 1917) and is the most abundant Ptinid in warehouses in Canada (Brown, 1940). Arnhardt (1929) and Brassler (1929) record it eating pollen in beehives in Germany.

Ptinus palliatus, Perris (figs. 16–20).

Ptinus palliatus, Perris, Mém. Acad. Lyon, **2**, 1849, p. 465.

♂. Length, 4·0–5·0 mm.; breadth, 1·8–2·3 mm. Elongate, subparallel-sided; cuticle piceous to brownish-piceous. *Head* between eyes with a very fine, median longitudinal impression; moderately densely clothed with long (one-third to one-half as long as third antennal segment), recumbent to suberect, pale testaceous to white, and golden-brown hairs. Surface with low, round to irregular granules which are about as coarse as facets of eyes and contiguous to separated by one diameter; anteriorly these granules are slightly finer, less distinct, and often replaced by shallow, indistinct punctures of about same size; surface between granules and punctures



Figs. 16–20. *Ptinus palliatus*, Perris: (16) dorsal view of ♂ genitalia; (17) right lateral view of same; (18) dorsal view of front tarsus of ♂; (19) umbilicate punctures of anterior part of metasternal disk; (20) posterior part of metasternal disk of ♀.

densely, microscopically punctate. *Pronotum* with a large, prominent, feebly transverse gibbosity occupying most of middle, and on each side of this gibbosity (on dorso-lateral part of pronotum) with a similar but smaller and less prominent gibbosity. Surface with round, low tubercles which are as coarse to half again as coarse as facets of eyes and usually nearly contiguous to occasionally separated by as much as one diameter ; with a single basal marginal row of coarse (about as coarse as tubercles), close punctures and on anterior fourth of disk with numerous similar punctures ; from tubercles and punctures arise suberect to erect, golden-brown and occasionally white hairs which are similar to those of head ; surface between tubercles and coarse punctures with numerous microscopic punctures and on basal fourth occasionally microscopically asperate. *Elytra* with cuticle of scutellar region, middle sides, and apical fourth slightly darker than elsewhere. Erect hairs of intervals golden-brown, usually about twice as long as discal strial punctures, and subequal ; intervals with irregular patches of long, white, recumbent hairs on humeral region, discal intervals, and apical fourth. Strial punctures on middle of disk deep, round to subquadrate, usually half as broad as intervals, and separated by one to slightly less than one diameter. *Scutellum* densely clothed with long, recumbent, white hairs. *Metasternum* with median longitudinal line broad, deep, and present on posterior half ; posterior half of disk strongly convex and anterior half strongly declivous ; posterior half of disk with microscopic punctures usually separated by one to three diameters ; anterior half of disk and sides with umbilicate punctures (fig. 19) which are one and a half to two times as coarse as facets of eyes and separated by one-fourth to nearly one diameter ; surface between umbilicate punctures microscopically asperate. Abdomen with all sternites densely, microscopically asperate ; middle of first sternite with a few coarse, indistinct, umbilicate punctures ; middle of second and third with a few oval to round, shallow, indistinct punctures which are as coarse to slightly coarser than facets of eyes. Tarsi with apex of fourth segment (fig. 18) broadly dilated. *Genitalia* (figs. 16–17) as figured.

♀. Differs from ♂ as follows : (1) eyes smaller and less convex ; (2) elytra slightly broader ; (3) posterior part of metasternal disk not as strongly convex ; (4) metasternal disk without a median longitudinal line but instead impressed as shown in fig. 20 ; and (5) middle of first three abdominal sternites with numerous umbilicate punctures which are slightly coarser than facets of eyes and surface between umbilicate punctures with microscopic punctures not asperate except along posterior margin of third sternite.

Distribution. England, France, Spain.

Comparative notes. It may be immediately distinguished from all other species dealt with in this paper by the large umbilicate punctures of the metasternum.

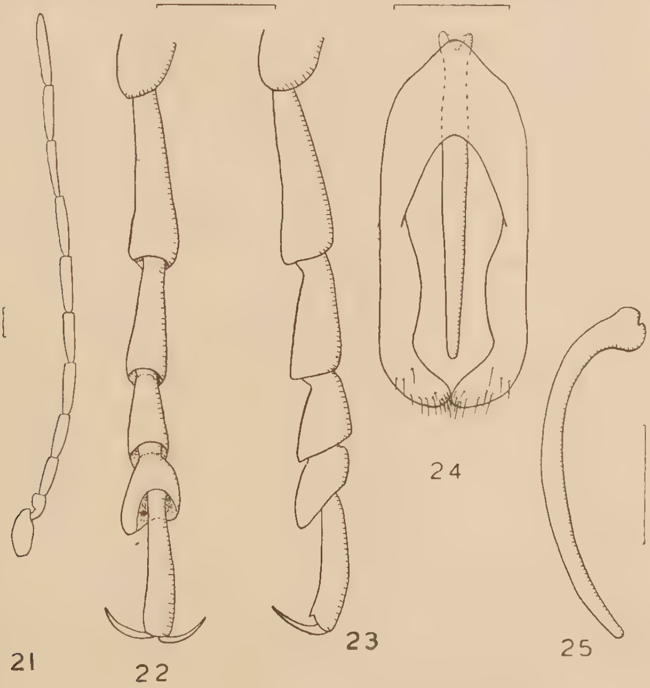
Habits. In old posts, etc. This species is of no economic importance.

Ptinus rufipes, Olivier (figs. 21–25).

Ptinus rufipes, Oliv., Entom. **2,** 1790, p. 8, pl. 2, f. 8.

♂. Length, 3·0–5·0 mm. ; breadth, 1·6–2·0 mm. Elongate, subparallel-sided ; cuticle black to piceous, antennae and legs rufo-piceous. *Head* with a fine, median longitudinal impression extending half-way to posterior margin ; moderately sparsely clothed with long (half as long as third antennal segment), recumbent, pale-testaceous to brownish-testaceous hairs. Surface with shallow punctures and low, indistinct granules which are slightly finer than facets of eyes and contiguous to separated by one diameter ; surface of most of front without these granules and punctures ; surface between granules and punctures and on front densely, microscopically asperate. *Pronotum* with a broad, median, moderately prominent gibbosity on basal third and with a similar dorso-lateral gibbosity on each side. Surface with round, low tubercles which are one-third to one-half coarser than facets of eyes and are nearly contiguous to separated by one diameter ; near base with a single row of deep, close punctures which are about as coarse as discal tubercles and on apical fifth of disk with a few similar but rounder and slightly sparser punctures ; from tubercles arise erect, testaceous hairs which are about three-fifths as long as third antennal segment ; surface between tubercles and coarse punctures with numerous microscopic punctures and on basal fourth often densely, microscopically asperate. *Elytra* with erect median hairs of intervals subequal, one and a half to twice as long as discal strial punctures, and golden-brown ; all intervals moderately densely clothed with paler, finer, shorter, and recumbent to suberect hairs. Strial punctures on middle of disk deep, round to subquadrate, three-fifths to half as broad as intervals, and separated longitudinally by slightly less than their diameters. *Scutellum* densely clothed with long, suberect, pale-grey hairs. *Metasternum* with median longitudinal line broad, moderately deep, and present on posterior half ; posterior half of disk strongly convex and anterior half strongly declivous ; disk with numerous microscopic punctures but anteriorly (and also on sides of metasternum) with round, shallow punctures as coarse to half again as coarse as facets of eyes and separated usually by one-half to one diameter ; surface between coarse punctures densely, microscopically asperate. Abdomen on middle of first three sternites with microscopic punctures separated usually by two to four diameters (denser on third sternite) and with a few round to obovate, shallow, indistinct punctures which are occasionally as coarse as facets of eyes. Tarsi with apex of fourth segment (figs. 22–23) broadly dilated. *Genitalia* (figs. 24–25) as figured.

♀. Differs from ♂ as follows : (1) second antennal segment as compared with third relatively longer in ♀ than in ♂ ; (2) on each side of middle of pronotal disk



Figs. 21–25. *Ptinus rufipes*, Oliv. : (21) antenna of ♂ ; (22) dorsal view of hind tarsus of ♂ ; (23) lateral view of same ; (24) dorsal view of ♂ genitalia ; (25) lateral view of median lobe.

with a broad, moderately prominent gibbosity ; (3) elytra broader and obovate instead of subparallel ; (4) strial punctures of middle of elytral disk usually slightly less than half as broad as intervals ; (5) each elytron with an irregularly transverse band of long, white, recumbent hairs on basal third and apical third and with a small patch of similar hairs near apex, whereas in ♂ there are no white hairs on elytra ; (6) elytral intervals without recumbent, grey hairs ; (7) erect hairs of elytral intervals long (often three to four times as long as strial punctures) and very unequal, those of odd intervals frequently being twice as long as those of even ; (8) scutellum broader and with white instead of pale grey hairs ; (9) metasternal disk shorter, flatter, and with median longitudinal line scarcely noticeably impressed ; and (10) on anterior two-fifths of fourth abdominal sternite is a coarse, median tubercle from which arises a tuft of long, dense, erect hairs.

Distribution. Widely distributed in Europe, but not yet recorded from Great Britain.

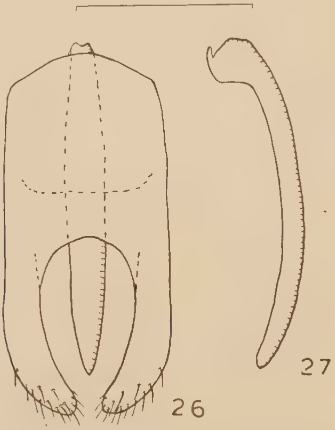
Comparative notes. The ♀ may be separated from that of all other species dealt with here by having a setose tubercle on fourth abdominal sternite. The ♂ may be readily distinguished by the structure of the pronotum and genitalia and the vestiture of the elytral intervals.

Habits. It is found on dead branches of trees, in barns, etc. and is mentioned by Zacher (1927, p. 111) as a pest of stored products.

Ptinus lichenum, Marsham (figs. 26–27).

Ptinus lichenum, Marsham, Coleopt. Brit., 1802, p. 89.

♂. Length, 2·3–3·5 mm. ; breadth, 0·95–1·5 mm. Elongate, subparallel-sided ; cuticle piceous and often with a feeble aeneous lustre ; antennae and legs rufo-piceous. *Head* with a fine, median longitudinal impression extending to posterior two-fifths ; densely clothed with white, recumbent hairs which are about half as long as third antennal segment and three to five times as long as broad ; also with numerous slightly longer, suberect to erect, golden-brown hairs. Surface of front densely, microscopically asperate ; anteriorly, basally, and at sides of head with low, irregular granules which are distinctly finer than facets of eyes and are usually separated by less than one to one diameter. *Pronotum* broadly, feebly, transversely gibbous on middle ; with a basal median longitudinal and on each side with a subapical patch of white,



Figs. 26–27. *Ptinus lichenum*, Marsham : (26) dorsal view of ♂ genitalia ; (27) left lateral view of median lobe.

scale-like hairs. Surface with low to moderately prominent, round tubercles which are as coarse to a fourth again as coarse as facets of eyes and are usually separated by one-half to one diameter ; with a single basal row of round, deep, moderately close punctures which are about as coarse as facets of eyes ; on anterior fourth with numerous similar but slightly sparser punctures ; surface between tubercles and punctures densely, microscopically asperate. *Elytra* with erect hairs of intervals equal and about one and a half times as long as strial punctures ; each elytron at apical third and at basal third with an irregularly transverse patch of white, recumbent, scale-like hairs which are two to three times as long as broad. Strial punctures on middle of disk deep, round to feebly oval, three-fifths to nearly as broad as intervals, and separated longitudinally by usually one diameter. *Scutellum* densely clothed with long, nearly recumbent, pale testaceous to nearly white hairs. *Metasternum* with median longitudinal line broad, deep, and confined to posterior half ; disk with posterior three-fifths strongly convex and anterior two-fifths strongly declivous ; surface of posterior half with microscopic punctures separated by two to five diameters ; surface of declivous portion more densely punctate, particularly anteriorly, and near anterior margin with an occasional shallow, round puncture which is distinctly coarser than an eye facet, the surface between these coarse punctures being densely, microscopically asperate ; sides of metasternum sculptured similarly to extreme anterior part of disk but posteriorly with coarse punctures nearly absent. Abdomen with middle region of first sternite with numerous microscopic and also with slightly coarser punctures ; middle region of second and third sternites densely, microscopically asperate and also with punctures which are distinctly finer than facets of eyes and are separated by one to three diameters. Tarsi with apex of fourth segment feebly dilated. *Genitalia* (figs. 26–27) as figured.

♀. Differs from ♂ as follows : (1) eyes smaller and less convex ; (2) antennae slightly shorter ; (3) elytra relatively broader and more oval ; (4) strial punctures of elytral disk only one-third to one-half as broad as intervals ; (5) metasternum shorter, with disk nearly flat, and with median longitudinal line confined to extreme base ; and (6) middle of second abdominal sternite without alutaceous microsculpture.

Distribution. Great Britain, France, Spain, Corsica.

Comparative notes. It is the only species dealt with in this paper which has the white hairs of the pronotum very broad and scale-like.

Habits. It is found on old palings, etc. (Fowler, 1890) and sometimes in houses (Pic, 1911). The larvae bore in the dry wood and bark of fig trees (Picard, 1919).

Ptinus exulans, Erichson (figs. 28–30).

Ptinus exulans, Er., Arch. f. Naturg. **8** (1), 1842, p. 147.

♂. Length, 2·5 mm. ; breadth, 1·3 mm. Broad, oblong, subparallel-sided ; cuticle rufo-piceous with head and pronotum slightly darker. *Head* moderately densely clothed with recumbent to suberect golden-brown hairs which are one-half to four-fifths as long as third antennal segment. Surface with round to oval, moderately shallow punctures which are distinctly coarser than facets of eyes and usually confluent to separated by one-third a diameter. *Pronotum* at middle transversely convex, without distinct gibbosities ; with a deep, narrow, transverse, and complete channel (usually more or less concealed by vestiture) on basal fourth. Surface with low to prominent, more or less round tubercles which are about one-half coarser than facets of eyes and contiguous to separated by nearly one diameter ; with a single basal marginal row of deep, coarse (as coarse as coarser tubercles of pronotal disk) punctures which are contiguous to separated by one-half a diameter and on anterior middle fourth or third of disk with numerous similar punctures ; surface between punctures and tubercles with a few microscopic punctures, nowhere asperate. From tubercles and punctures arise suberect to erect, golden-brown hairs which are as long to half again as long as third antennal segment ; hairs generally denser just in front of transverse basal channel, particularly on dorso-lateral sides ; at sides from basal fourth to apical half with a broad, longitudinal band of dense, white semi-recumbent hairs and in front and slightly mesal to this band with a small patch of similar white hairs. *Elytra* with erect hairs of intervals golden-brown, usually about four to five times as long as discal strial punctures, and subequal ; hairs of strial punctures similar to those of intervals but recumbent to suberect and only one-half to two-thirds as long ; with dense, long, slender, recumbent, white hairs forming an oval patch near humeri, a similar patch on middle of disk on second and third intervals, and another similar patch slightly behind middle on seventh and eighth intervals ; humeri and basal region with moderately dense, long, recumbent, golden-brown hairs on intervals. Strial punctures on middle of disk deep, feebly oblong, slightly less than half as broad as intervals, and separated longitudinally by a fourth to nearly a half diameter. *Scutellum* with a dense patch of white, moderately short, semi-recumbent hairs. *Metasternum* with disk nearly flat and with a broad, moderately deep, longitudinal impression confined to basal half ; disk densely,

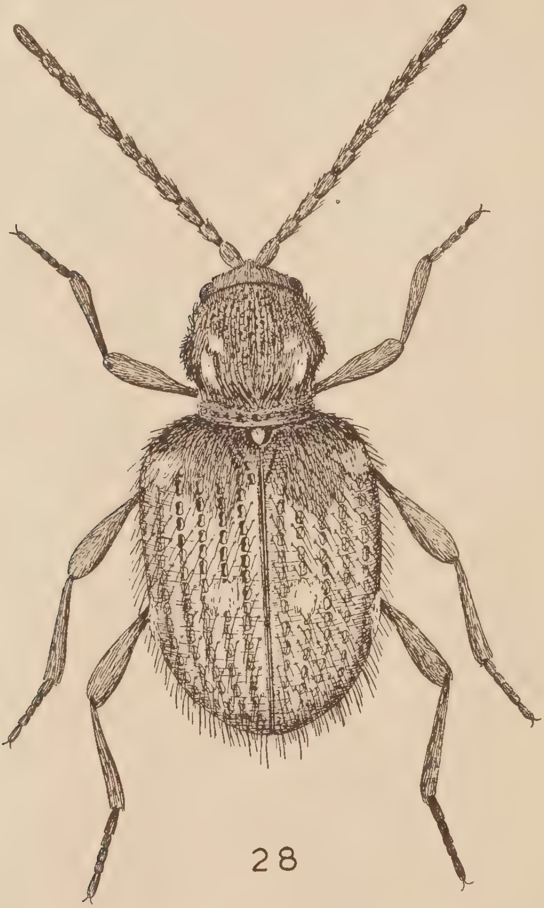


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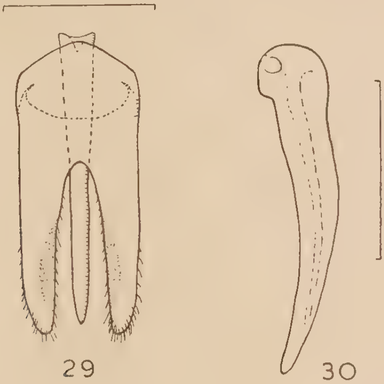
Fig. 28. *Ptinus exulans*, Er.

microscopically punctate ; extreme anterior part of disk and most of metasternal sides with round to oval, moderately shallow punctures which are half again to three times as coarse as facets of eyes and separated by one-fourth to one-half a diameter ; surface between coarse punctures moderately densely, microscopically punctate. Abdomen with middle region of first three sternites moderately densely, microscopically punctate and also with round to oval, shallow punctures which are about a third coarser than facets of eyes and are separated by one to three diameters. Tarsi with apex of fourth segment not dilated. *Genitalia* (figs. 29–30) as figured.



Figs. 29–30. *Ptinus exulans,* Er. : (29) dorsal view of ♂ genitalia ; (30) lateral view of median lobe.

♀. Externally similar to ♂.

Distribution. Australia, Tasmania, Europe, Asia.

Comparative notes. The structure of the pronotum and the arrangement of white hairs on the pronotum and on the elytra will serve to distinguish it from all related species.

Habits. It has been recorded from warehouses in Hamburg (Reitter, 1911). Zacher (1927, p. 111) mentions it as a pest of stored products but gives no details of any damage done by it.

Ptinus sexpunctatus, Panzer (figs. 31–35).

Ptinus sexpunctatus Panzer, Ins. Germ. **1,** 1792, p. 114.

♂. Length, 2·4–3·5 mm. ; breadth, 1·1–1·5 mm. Elongate, subparallel-sided ; cuticle brownish-piceous. *Head* with a shallow, indistinct, median longitudinal impression on front ; densely clothed with white, recumbent hairs which are one-third to one-half as long as third antennal segment and are three to five times as long as broad ; near sides with numerous and elsewhere with an occasional longer, narrower, brownish, suberect hairs. Surface densely, rugosely granulate (granules finer than facets of eyes) and also densely, microscopically asperate. *Pronotum* with middle of disk feebly gibbous and also with a broad, moderately prominent, dorso-lateral gibbosity on each side. Surface with low to moderately prominent tubercles which are about one-third coarser than facets of eyes and usually separated by one-half to one diameter ; surface also with deep, more or less round punctures which are slightly finer than facets of eyes and are usually separated by less than one to one diameter ; surface between tubercles and punctures densely, microscopically asperate ; with a single basal marginal row of deep punctures which are about as coarse as those of disk and are frequently confluent, seldom separated by more than half a diameter.

Surface with stout, moderately sparse, erect, brownish-testaceous hairs each of which arises from a tubercle, never from a puncture. *Elytra* with erect hairs of intervals moderately short (one and a half times as long as discal strial punctures) and subequal; hairs arising from anterior margins of strial punctures not as long as strial punctures and recumbent to suberect; intervals with patches of flat, obovate (about one and a half times as long as broad), dense, white hairs as follows: (1) a more or less oval patch behind humeri on intervals four to ten; (2) a slightly smaller oval patch on apical fourth on intervals three to six; and (3) slightly anteriorly but more or less connected with second patch a still smaller suboval patch on intervals seven to nine; sutural and second intervals occasionally with a few white scales on disk. Strial punctures on middle of disk deep, rectangular (about one-third longer than broad), one-third to one-half as broad as intervals, and separated longitudinally by about half their lengths. *Scutellum* densely clothed for the most part with moderately

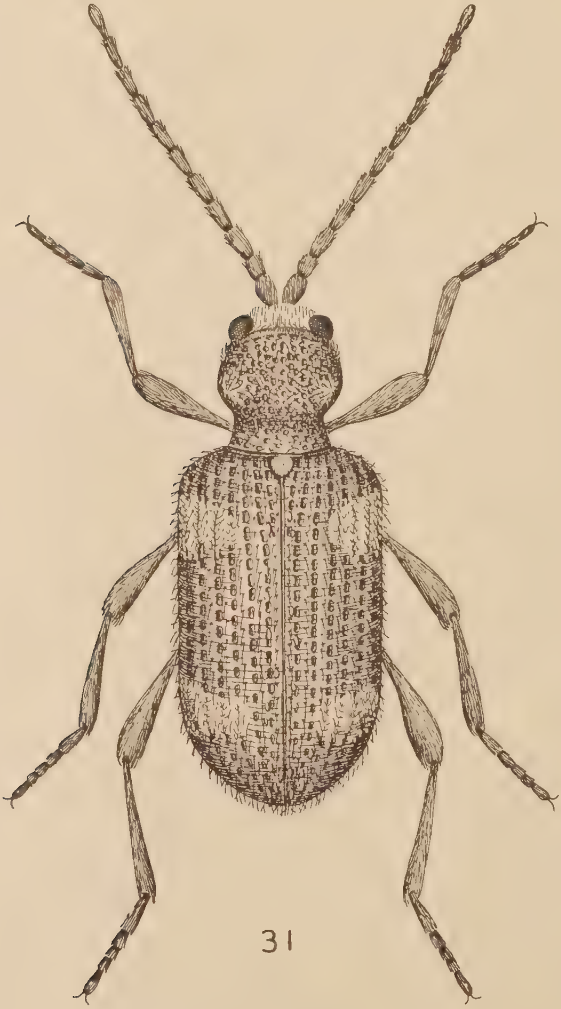
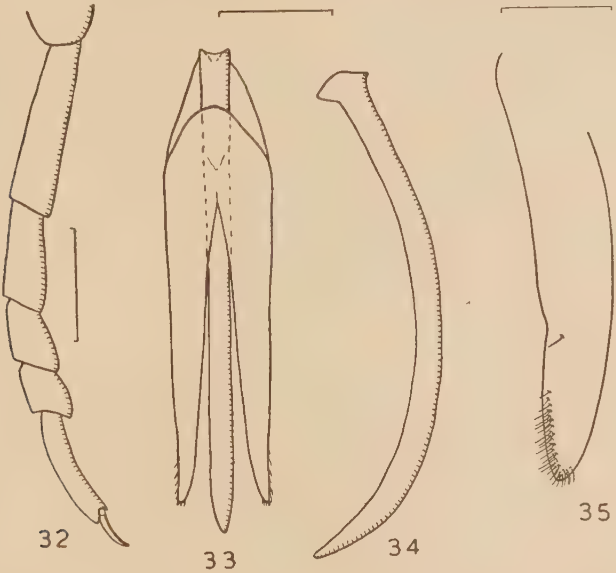


Fig. 31. *Ptinus sexpunctatus*, Panzer, ♀.

short, slender, pale-testaceous to nearly white hairs. *Metasternum* with median longitudinal line narrow, moderately deep, and confined to basal half ; surface of disk with oval to moderately elongate (twice as long as broad) punctures which are slightly narrower than facets of eyes ; surface between these punctures with shallow, microscopic punctures which are separated by two to three diameters ; sides of metasternum with punctures deeper, coarser, and more regularly elongate. Abdomen with middle of first three sternites punctate somewhat like metasternal disk. Tarsi with apex of fourth segment (fig. 32) not dilated. *Genitalia* (figs. 33–35) as figured.



Figs. 32–35. *Ptinus sexpunctatus*, Panzer : (32) lateral view of hind tarsus of ♂ ; (33) dorsal view of ♂ genitalia ; (34) lateral view of median lobe ; (35) lateral outer view of paramere.

♀. Externally similar to ♂ but with metasternum shorter, metasternal disk slightly more coarsely punctate, and median longitudinal line of metasternum broader and confined to caudal fifth.

Distribution. Great Britain, France, Corsica.

Comparative notes. This species may be distinguished from all those dealt with here by the fact that the setae in the discal strial punctures of the elytra are usually shorter instead of longer than their respective punctures.

Habits. It is often found in the nests of bees of the genus *Osmia* (Morley, 1919 ; Hamm, 1924) and is possibly associated with the bee *Anthophora pilipes*, F. (Hamm, 1924). A single specimen has been bred from the nest of a house martin (Blair, 1924). It has been recorded from houses (Fowler, 1890 ; Ryle, 1924) and damaging a lead roof (Laing, 1919).

Ptinus tectus, Boieldieu (figs. 36–39).

Ptinus tectus, Boie., Ann. Soc. ent. Fr. (3) **4,** 1856, p. 652.

Ptinus ocellus, Brown, Canad. Ent. **61,** 1929, p. 109 ; op. cit. **72,** 1940, p. 120.

Brown (1929) described *Ptinus ocellus* from specimens infesting fish-meal in British Columbia. Hatch (1933) showed this species to be a synonym of *P. tectus*, Boie. Brown (1940, p. 120) agrees that his species is a synonym of *P. tectus* but nevertheless maintains that his name, *P. ocellus*, must be retained as the name *P. tectus* is not valid for this insect. Apart from the confusion necessarily caused by changing the name of a common insect of economic importance, it seems clear to me that the name *P. tectus* must be retained for the Ptinid now known by that name.

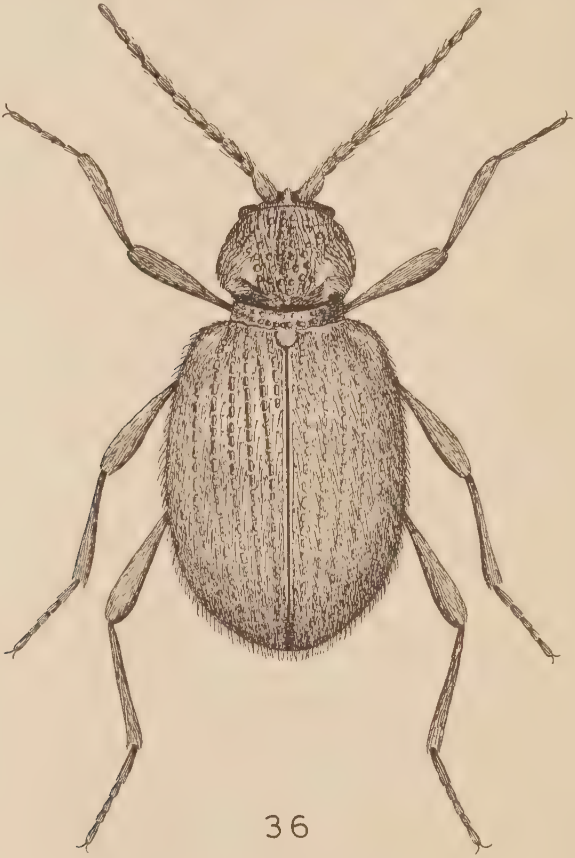
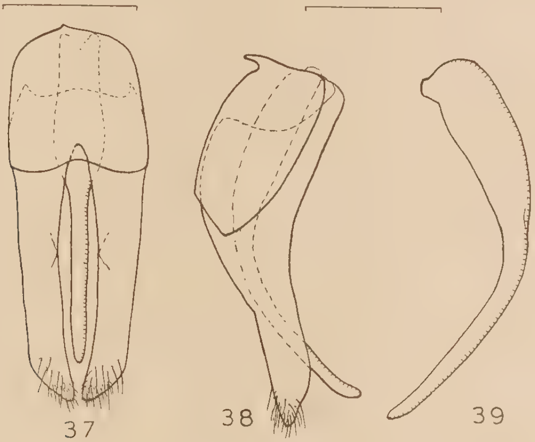


Fig. 36. *Ptinus tectus*, Boie.

Under the name *Ptinus tectus*, a Tasmanian insect was described by Boieldieu (1856) which is clearly from the description a true *Ptinus* and has subsequently—by comparison with the type (Beare, 1904)—been shown to be identical with the cosmopolitan insect known under this name. Boieldieu erroneously gives *Ptinus pilosus*, White 1846, as a synonym of *Ptinus tectus*, Boie., and later states that he is obliged to rename 'this species' on account of its being a homonym of *Ptinus pilosus*, Müller 1821. Blair (1928) has shown that *P. pilosus*, White, is not a Ptinid but an Anobiid which belongs in the genus *Dorcatoma*. The description of *P. tectus* was clearly based on a species of *Ptinus* actually examined by Boieldieu but wrongly determined by him as the Anobiid, *Ptinus pilosus*, White. Boieldieu in effect did two things; (*a*) described a new species, *Ptinus tectus*; and (*b*) renamed *Ptinus pilosus*, White 1846 (*nec Ptinus pilosus*, Müller 1821) as *Ptinus tectus*. *P. tectus*, Boie. (*a*) is not identical with *P. tectus*, Boie. (*b*). The two names are homonymous, therefore *P. tectus* (*b*), over which *P. tectus* (*a*) has place priority, must be renamed again. I herewith propose the name *Dorcatoma pilosellus*, **nom. nov.** = *Ptinus pilosellus*.

♂. Length, 2·5–4·0 mm.; breadth, 1·2–1·7 mm. Broad, obovate to feebly subparallel-sided; cuticle brownish-piceous. *Head* densely clothed with fine, short, brownish-yellow, recumbent hairs and also with numerous slightly longer and stouter, golden-brown hairs. Carina between antennal bases slightly broader than that of other species dealt with here. Surface on front with round to oval, shallow punctures which are slightly finer than to a fourth coarser than facets of eyes and are usually confluent to separated by half a diameter; surface between coarse punctures densely, microscopically asperate. *Pronotum* feebly gibbous across middle and with the dorso-lateral portion slightly more prominent; on basal fourth with a complete, transverse, broad, more or less concealed channel (similar to that of *P. exulans*). Surface with deep, round to oval punctures which are one and a half to two times as coarse as facets of eyes and usually separated by one-half to one diameter; on apical half with a narrow, median longitudinal, non-impressed line which is more or less free from coarse punctures; coarse punctures on gibbous sides of disk frequently replaced by low, indistinct granules; with a single basal marginal row of close punctures which are as coarse as those of disk; surface between coarse punctures with dense, microscopic punctures. Pubescence of two types as follows: (1) densely clothed with fine, recumbent to erect, yellowish-brown hairs which arise from the microscopic punctures, these hairs being testaceous at dorso-lateral sides where the transverse channel of basal fourth is deeper and broader; and (2) with erect, golden-brown hairs which are coarser, one-third to two times as long, and which arise from coarse punctures. *Elytra* with erect hairs of intervals golden-brown and more or less equal in length (one and a half to two times as long as discal strial punctures); all intervals densely and uniformly clothed with recumbent, yellowish-brown hairs which are about as long as strial punctures. Strial punctures on middle of disk deep, obovate to rectangular, one-third to two-fifths as broad as intervals, and separated longitudinally by about one diameter; setae arising from strial punctures* half again as long as punctures. *Scutellum* clothed like adjacent elytral intervals but



Figs. 37–39. *Ptinus tectus*, Boie.: (37) dorsal view of ♂ genitalia; (38) right lateral view of same; (39) left lateral view of median lobe.

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* Brown (1933) wrongly claims that there are no setae arising from elytral strial punctures.

without longer hairs and with short hairs generally slightly darker. *Metasternum* with median longitudinal line feebly impressed and confined to basal fourth ; disk feebly convex and surface with two types of punctures as follows : (1) oval, moderately deep punctures which are one-third coarser to nearly two times as coarse as facets of eyes and separated by one-fourth to one diameter ; and (2) microscopic punctures usually separated by one to two diameters ; both types of punctures become sparser caudally ; sides of metasternum sculptured like anterior part of disk but slightly more coarsely so. Abdomen with middle of first sternite sculptured like posterior sides of metasternal disk ; middle of second and third sternites with coarse punctures finer and sparser while microscopic punctures are denser. Tarsi with apex of fourth segment not dilated. *Genitalia* (figs. 37–39) as figured.

♀. Externally similar to ♂.

Distribution. Cosmopolitan. It has been found in Great Britain since 1901.

Comparative notes. It may be readily distinguished from all other species by the broadly oval body, the coarsely punctate head and pronotum, the clothing of the elytra and absence of white hairs or scales anywhere on the body, the similarity of the two sexes, and the unique structure of the male genitalia.

Habits. It has been recorded living in a great variety of dried organic materials, *e.g.* dried insects (Walsh, 1923) ; eating holes in carpets (Carpenter, 1920) ; poultry food containing dried yeast, bran, and crushed crabs (König, 1936) ; fish-meal (Scholz, 1920 ; Friederichs, 1932 ; Essig, 1933 ; Brown, 1940) ; stored hops (Theobald, 1927) ; dried leaves and flowers of *Hyoscyamus niger* and *Datura stramonium* (Madel, 1937) ; nutmegs, almonds, ginger, figs, sultanas, dried pears, and dried apricots (Richards & Herford, 1930) ; cayenne pepper (Walker, 1915 ; von Lengerken, 1929 *b*) ; casein (Carpenter, 1920) ; cacao (Knapp, 1921 ; Zacher, 1926 ; Munro & Thomson, 1929 ; Richards & Herford, 1930) ; chocolate powder (Walker, 1915) ; desiccated soup (Walsh, 1923) ; and maize and rye (Zacher, 1927).

It has been found in houses, granaries, warehouses, flour mills, bakers' shops, and glazed-paper and biscuit factories, etc. When in large numbers the larvae are very destructive, matting the food together and covering it with webbing. For papers on the life-history and control the reader is referred to Scholz (1920) ; von Lengerken (1929 *a* and *c*) ; Friederichs (1932) and König (1936).

Ptinus hirtellus, Sturm (figs. 40–43).

Ptinus testaceus, Olivier, Entom. **2,** 1790, p. 9, t. 2, f. 9.
Ptinus brunneus, Duftschmid, Fauna Austr. **3,** 1825, p. 65.
Ptinus hirtellus, Sturm, Deutsch. Ins. **12,** 1837, p. 80, t. 258, f. A.

The Ptinid generally known by the name of *Ptinus brunneus,* Dufts., must now be known as *P. hirtellus,* Sturm. *P. testaceus,* Oliv., is a homonym of *P. testaceus,* Thunb. 1784, *P. brunneus,* Dufts., is a homonym of *P. brunneus,* Gmelin 1789, and *P. hirtellus,* Sturm, is now the earliest available name for this species.

♀. Length, 2·3–3·2 mm. ; breadth, 1·2–1·58 mm. Obovate to broadly oval ; cuticle dark to moderately pale rufo-piceous. *Head* moderately densely clothed with recumbent (occasionally suberect near antennae and at sides), testaceous hairs which are about four-fifths as long as third antennal segment. Surface with a feeble, median longitudinal impression ; with low, indistinct granules about one-half to two-thirds as coarse as facets of eyes and contiguous to separated by two diameters ; surface on middle of front with granules distinctly sparser ; surface between granules polished and nearly smooth. *Pronotum* with shape as figured (fig. 40). Surface with low to prominent tubercles which are as coarse to half again as coarse as facets of eyes and are usually separated by one-half to one diameter ; surface between tubercles with irregularly shaped punctures which are about as dense but usually slightly finer than tubercles ; with a single basal marginal row of deep, coarse, close punctures. Erect, testaceous hairs, which are about as long as third antennal segment, arise only from tubercles and some of discal ones are arranged in four groups as shown in fig. 40. *Elytra* with erect hairs of intervals usually two or three

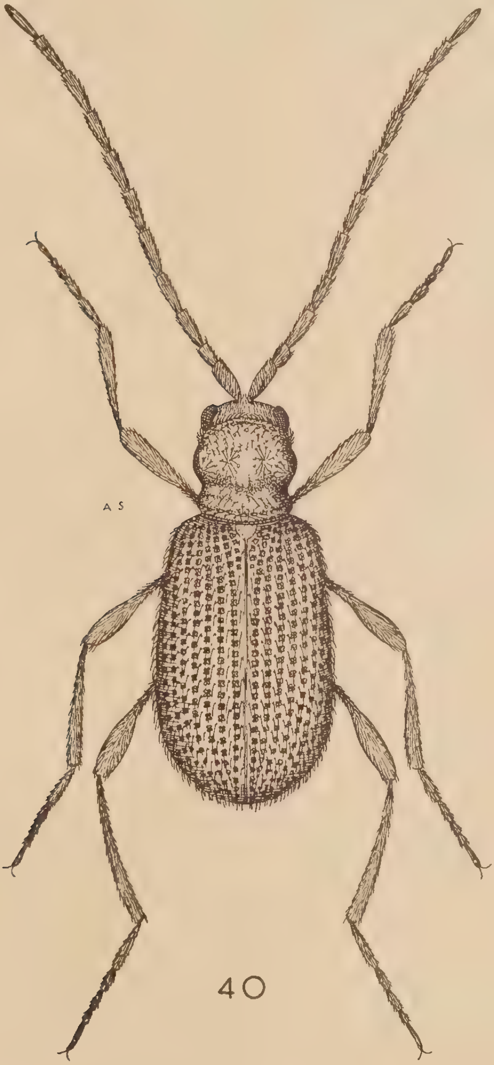
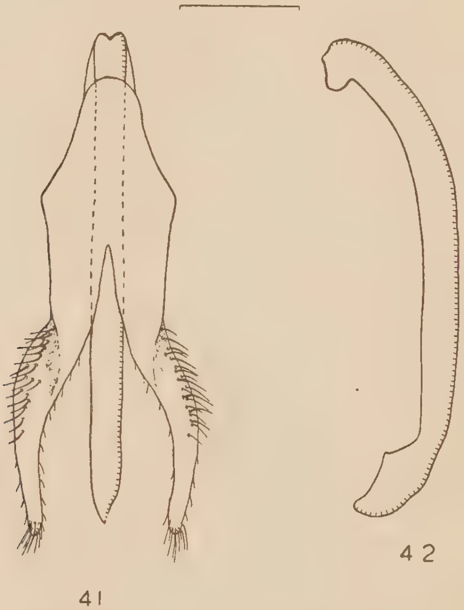


Fig. 40. *Ptinus hirtellus*, Sturm, ♂.

times as long as discal strial punctures and unequal, those of alternate intervals often one-third longer and sometimes twice as long as those of even intervals ; intervals three to ten on basal fourth with or without numerous recumbent, testaceous hairs which are nearly as long as erect hairs ; setae of strial punctures recumbent to suberect and one-half longer than to twice as long as strial punctures. Strial punctures on middle of disk deep, subquadrate, three-fifths to as broad as intervals, and separated longitudinally by one-half to one diameter. *Scutellum* densely clothed with recumbent, pale-testaceous hairs. *Metasternum* with median longitudinal line broad and confined to extreme caudal margin ; disk nearly flat and with deep, round to oval punctures which are about as coarse as facets of eyes and usually separated by one to two diameters ; surface between coarse punctures with numerous microscopic punctures and an occasional microscopic tubercle ; sides of metasternum with punctures slightly coarser, denser, more elongate and microscopic punctures nearly entirely replaced by equally fine tubercles. Abdomen with punctures of middle region of first three sternites finer, sparser, and more elongate (occasionally three times as long as broad) than those of metasternal disk and without microscopic tubercles but only with sparse, microscopic punctures. Tarsi with apex of fourth segment not dilated.



Figs. 41–42. *Ptinus hirtellus*, Sturm : (41) dorsal view of ♂ genitalia ; (42) left lateral view of median lobe.

♂*. May be distinguished from ♀ in the following particulars : (1) Body longer and subparallel-sided instead of obovate ; (2) eyes larger and more prominent ; (3) antennae longer and third segment nearly twice as long as second (0·21 : 0·137 mm.) instead of only slightly longer (0·16 : 0·13 mm.) ; (4) pronotum with tubercles less prominent and sparser and coarse punctures indistinct or absent on most of middle of disk ; (5) basal region of pronotal disk in front of constriction with a feeble, median gibbosity which is absent in ♀ (*cf.* figs. 40, 43) ; (6) erect hairs of elytral intervals shorter and equal in length instead of noticeably unequal ; (7) metasternal disk longer, moderately strongly convex instead of flat, and with median longitudinal line present on caudal third ; (8) punctures of middle region of first three abdominal sternites usually narrower and relatively more elongate ; and (9) legs relatively longer and more slender.

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* Patton (1931) claims that there is no sexual dimorphism in this species.

Distribution. Cosmopolitan.

Comparative notes. This species is very close to *P. latro* and may be distinguished from the latter as shown in the key.

Habits. It is mainly a scavenger and has been recorded as living on faeces of rats and damaging books, feathers, skins, dried mushrooms, drugs, and roots (Zacher, 1927). It has been found in cacao, sugar, and dried fruit warehouses (Richards & Herford, 1930) and in granaries (Boieldieu, 1856). De Stefani (1921) records it from the last fragments of a corpse.

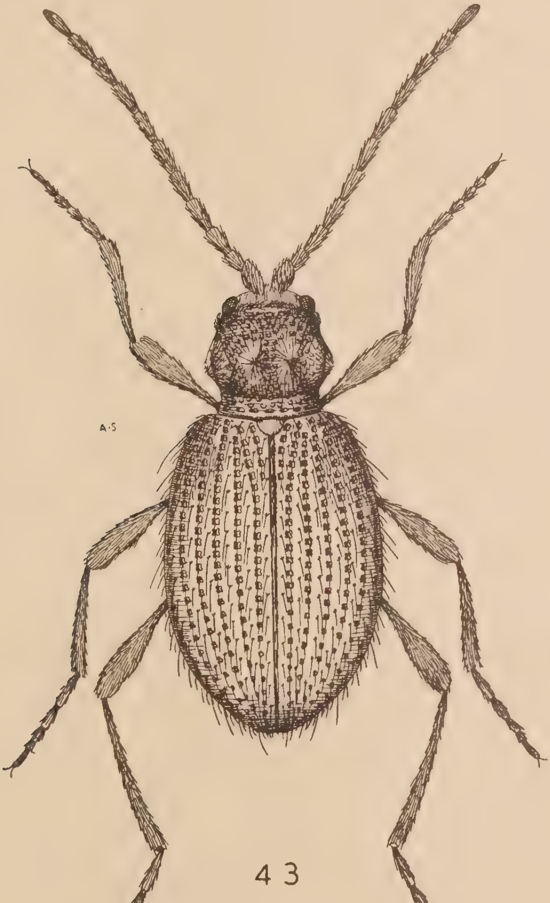

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Fig. 43. *Ptinus hirtellus*, Sturm, ♀.

Ptinus latro, Fabricius (fig. 44).

Ptinus latro, Fabricius, Syst. Ent. 1775, p. 63.

♀. Length, 3·0–4·5 mm.; breadth, 1·4–2·1 mm. Externally very close to *P. hirtellus*, Sturm, but differs in the following particulars: (1) slightly longer and not as broadly oval; (2) elytra with erect hairs of intervals coarser and on apical half equal instead of very unequal in length; (3) intervals three to ten on basal fourth never with a patch of recumbent hairs; (4) discal strial punctures usually

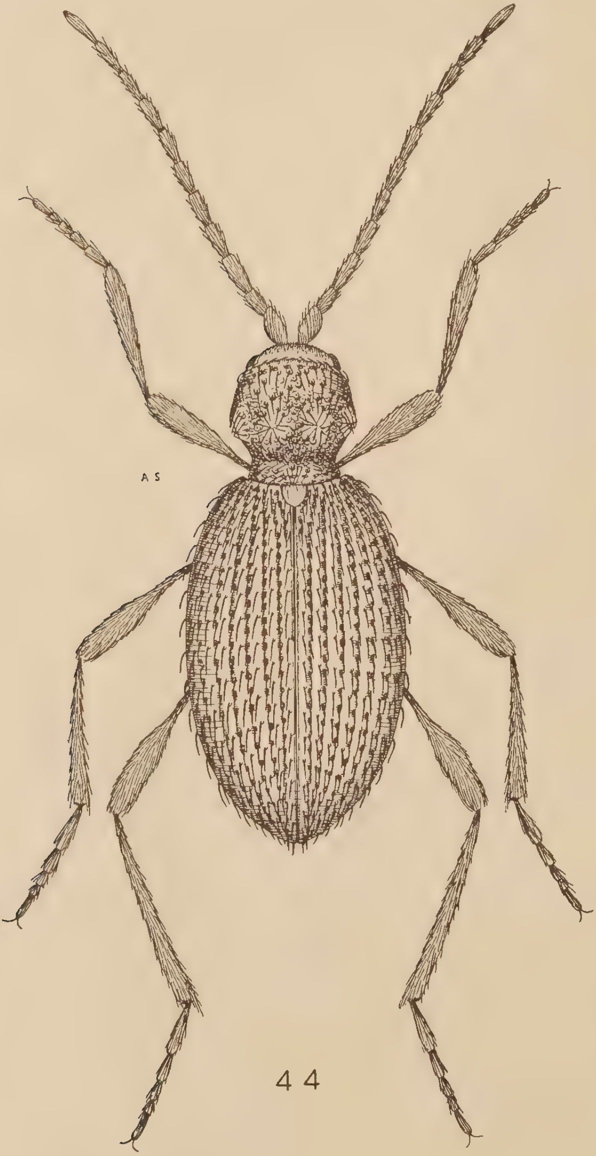

Fig. 44. *Ptinus latro*, F., ♀.

less than half as broad as intervals and each puncture set in a slight depression instead of having its border well-defined; and (5) punctures of metasternal disk and middle of first abdominal sternite two to three times as long as broad, whereas in *P. hirtellus* these punctures are round to oval, seldom three times as long as broad.

♂. Differs from ♀ in the same particulars (except for erect hairs of intervals and punctures of abdominal sternites) as the ♂ of *P. hirtellus* differs from its ♀. Erect hairs of intervals are equal in length but are generally slightly more slender in ♂ than in ♀. Punctures of metasternum and middle region of first three abdominal sternites are longer, denser, and relatively narrower than those of ♀.

Distribution. Nearly cosmopolitan.

Comparative notes. This is very close to *P. hirtellus*, Sturm, and the ♀♀ of the two may be distinguished as shown above. The ♂♂ appear to have identical genitalia, and I have been able to find no very reliable character for separating them. Generally ♂♂ may be separated from those of *P. hirtellus* by their finer discal strial punctures, on apical half those of second being separated longitudinally usually by much more than their diameters, whereas those of *P. hirtellus* are separated longitudinally by less than one to one diameter. According to Reitter (1911) the ♂♂ have the elytral strial punctures much narrower than the intervals, whereas ♂♂ of *P. hirtellus* have these punctures much broader than the intervals.

Habits. It is found in houses (Fowler, 1890), warehouses (Richards & Herford, 1930; Brown, 1940), and granaries (Boieldieu, 1856). It has been found in sugar and cacao warehouses (Richards & Herford, 1930), in stored grain and bran (Zacher, 1927), and causing considerable damage to stored tobacco seeds in Crimea (Keleberdinskii & Grabovskii, 1936).

Ptinus fur, Linnaeus (figs. 45–49).

Cerambyx fur, L., Syst. Nat. **10**, 1758, p. 393.

♂. Length, 2·0–4·3 mm.; breadth, 1·1–1·6 mm. Elongate, subparallel-sided; cuticle dark to pale brownish-piceous. *Head* with a fine, shallow or moderately deep, median longitudinal line on front; moderately densely clothed with recumbent to suberect, testaceous hairs which are one-fourth to one-third as long as third antennal segment. Surface with low, indistinct, dense granules which are about two-thirds

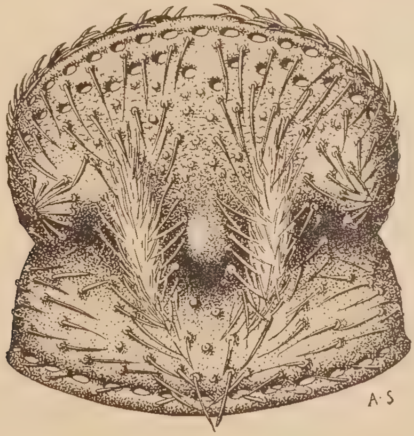

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Fig. 45. *Ptinus fur*, L., ♂

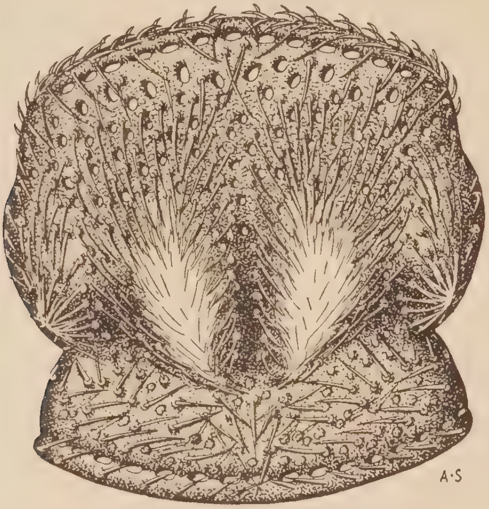

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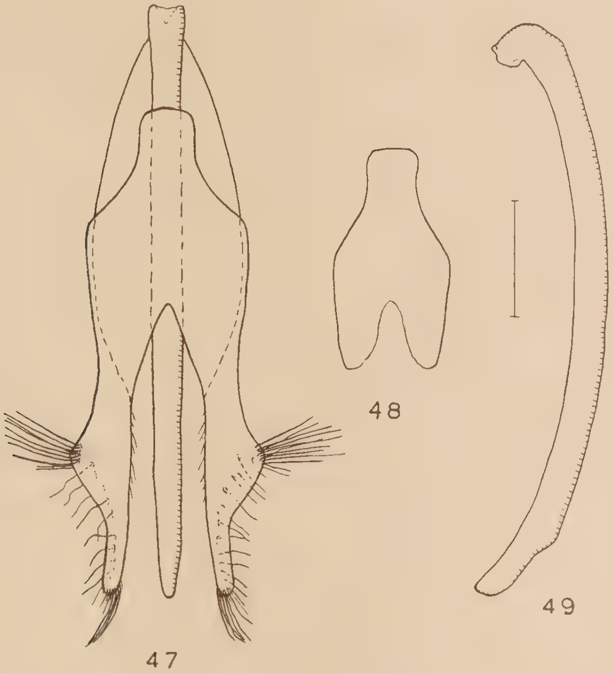
Fig. 46. *Ptinus fur*, L., ♀.

as coarse as facets of eyes ; surface on middle of front with granules sparser and less distinct ; surface between granules densely, microscopically asperate. *Pronotum* with shape and impression as shown in fig. 45. Surface with more or less round, low to moderately prominent tubercles which are slightly finer to slightly coarser than facets of eyes and are separated by one-half to one and a half diameters ; with deep, irregularly shaped punctures which are sometimes coarser than tubercles and separated by less than one to one or two diameters ; on middle of disk with the coarse punctures indistinct or absent ; with a single basal marginal row of deep, coarse, close, usually transverse punctures ; surface between coarse punctures and tubercles, particularly anteriorly and basally, densely, microscopically asperate. From tubercles arise suberect to erect, testaceous hairs which are one-third as long to as long as third antennal segment ; from basal half to basal sixth on each side of middle these hairs are slightly finer, paler, and grouped together to form two moderately distinct cushions which converge feebly towards base. *Elytra* with erect hairs of intervals one and a half times as long as strial punctures and usually equal in length ; setae arising from strial punctures about twice as long as their punctures ; white, coarse (four to five times as long as broad), recumbent hairs forming two transverse patches on each elytron, one on third to tenth intervals on basal fourth and one on second to tenth intervals on apical fourth ; also with an occasional white hair on middle discal intervals and on most of intervals of basal fourth. Strial punctures on middle of disk deep, subquadrate, about as broad as intervals, and separated longitudinally by one-half to nearly one diameter. *Scutellum* densely clothed with short, recumbent, pale-testaceous hairs. *Metasternum* with median longitudinal line broad, moderately deep, and confined to basal two-fifths ; disk strongly convex on posterior half and strongly declivous on anterior half ; surface of disk with punctures oval to twice as long as broad, nearly as coarse as facets of eyes, and usually separated by one to three diameters ; surface between coarse punctures with microscopic punctures separated usually by two to three diameters ; sides of metasternum with coarse punctures dense and slightly coarser while microscopic punctures are generally replaced by low granules which are slightly coarser than punctures they replace. Abdomen with middle of first three sternites sculptured like sides of metasternum but with coarse punctures longer and relatively narrower, often being five to six times as long as broad on second and third sternites. Tarsi with apex of fourth segment not dilated. *Genitalia* (figs. 47–49) as figured.



Figs. 47–49. *Ptinus fur*, L.; (47) dorsal view of male genitalia; (48) dorsal view of basal piece; (49) left lateral view of median lobe.

♀. Differs from ♂ as follows: (1) body obovate instead of subparallel-sided; (2) eyes smaller and less strongly convex; (3) antennae relatively shorter, and third segment, when compared with second, relatively shorter than that of ♂; (4) pronotum without a median gibbosity in front of constriction (*cf.* figs. 45, 46) and with hairy or subtomentose cushions denser, broader, and much more distinct; (5) metasternum much shorter, median longitudinal line broader and confined to basal sixth, disk nearly flat instead of with posterior half strongly convex, and punctures of disk denser and round to oval, seldom elongate; (6) middle of first three abdominal sternites with round to elongate punctures but never with punctures more than about three times as long as broad, whereas in ♂ these punctures are often five to six times as long as broad; and (7) legs relatively shorter and broader.

Distribution. Cosmopolitan.

Comparative notes. Of the species dealt with in this paper it can only be compared with *P. pusillus*, Sturm, and from the latter may be distinguished as follows: (1) with a moderately prominent, subtomentose cushion on each side of pronotum at middle, whereas in *pusillus* there is no trace of such a cushion on pronotum; (2) the ♂ has the punctures of the disk and sides of metasternum and middle region of first three abdominal sternites frequently elongate, those of abdomen often being five to six times as long as broad, whereas the ♂ of *pusillus* has these punctures round to feebly oval ; (3) the apical tibial spurs of the ♂ are slender, short, and nearly straight, whereas in *pusillus* the ♂ has those of middle and hind tibiae very long and strongly curved (fig. 55) ; and (4) the ♂ genitalia of the two species are very different (*cf.* figs. 47 and 52).

Habits. It is an omnivorous feeder attacking a wide variety of dried and decaying animal and vegetable matter, *e.g.* insect specimens (Fowler, 1890 ; Curran, 1925 ; Hirose, 1936 ; Görnitz, 1937) ; wasp combs (Hüsing, 1935) ; feathers and animal skins (Zacher, 1927 ; Clark, 1929) ; stuffed birds (Curran, 1925) ; dried plants in herbaria (Kemner, 1933) ; stored seeds of henbane (Carpenter, 1920), *Scorzonera tau-saghiz* (Dobrovol'skii, 1935), and *Nicotiana rustica* (Shelyuzhko, 1935) ; sacks of ginger (Richards & Herford, 1930) ; West African cacao (Knapp, 1921) ; dates (Miller, 1922) ; paprika pepper (Šámal, 1930) ; rye-bread (Schøyen, 1916) ; flour (Zvierezomb-Zubovsky, 1918 ; Curran, 1925) ; stored cereals (Frickhinger, 1924 ; Gavalov, 1927 ; Mamaev, 1929) ; grain (Portchinsky, 1913); partitions and ceilings of papered canvas in house (Herold, 1933) ; and destroying sacks in which grain, cotton seeds, etc. are stored.

P. fur is commonly found in houses, granaries, warehouses, and museums.

Ptinus pusillus, Sturm (figs. 50–55).

Ptinus pusillus, Sturm, Deutschl. Ins. **12,** 1837, p. 65, t, 251, f. A.

♂. Length, 1·8–3·0 mm. ; breadth, 0·82–1·2 mm. Subparallel-sided to feebly obovate ; cuticle dark rufo-piceous to brownish-testaceous. *Head* densely clothed with brownish-testaceous, recumbent to suberect hairs which are about half as long as third antennal segment. Surface with low, round to irregularly shaped tubercles which are about two-thirds as coarse as facets of eyes and are contiguous to separated by one diameter ; surface between these punctures densely, microscopically punctate and asperate. *Pronotum* with shape and gibbosities as shown in fig. 50. Surface with low to prominent, more or less round tubercles which are usually about one-fourth coarser than facets of eyes and are separated by one-fourth to one diameter ; anterior fourth of disk with a few deep punctures which are about as coarse as tubercles ; at base with a single marginal row of deep, coarse, close punctures ; surface between coarse punctures and tubercles with numerous microscopic punctures. From each tubercle arises a brownish-testaceous, suberect to erect hair which is one-half to two-thirds as long as third antennal segment. *Elytra* with erect hairs of intervals equal in length and one and a half times as long as discal strial punctures ; hairs arising from strial punctures recumbent and nearly as long as those of intervals. Each elytron with two irregularly transverse patches of moderately dense, white, recumbent, scale-like hairs (two to three times as long as broad) as follows : (1) on basal sixth or fifth on second to ninth intervals ; and (2) on apical fourth to third on second to ninth intervals. Strial punctures on middle of disk moderately deep, subquadrate, slightly narrower to one-fourth broader than intervals, and separated longitudinally by usually one-half their diameters. *Scutellum* densely clothed with moderately short, recumbent, testaceous hairs. *Metasternum* with median longitudinal line very deep, broad, oval, and confined to posterior fourth ; disk flat to feebly concave and with round punctures which are about two-thirds as coarse as facets of eyes and are usually separated by two to four diameters ; surface between these punctures with scarcely noticeable microscopic punctures which are separated by one to three diameters ; sides of metasternum sculptured like disk but with punctures slightly coarser. Abdomen with middle of first two sternites sculptured like metasternal disk and middle of third more finely and sparsely sculptured. Tarsi with apex of fourth segment not dilated. *Genitalia* (figs. 52–54) as figured.

♀. May be distinguished from ♂ as follows : (1) eyes smaller and less strongly convex ; (2) antennae relatively shorter ; (3) elytra generally slightly broader

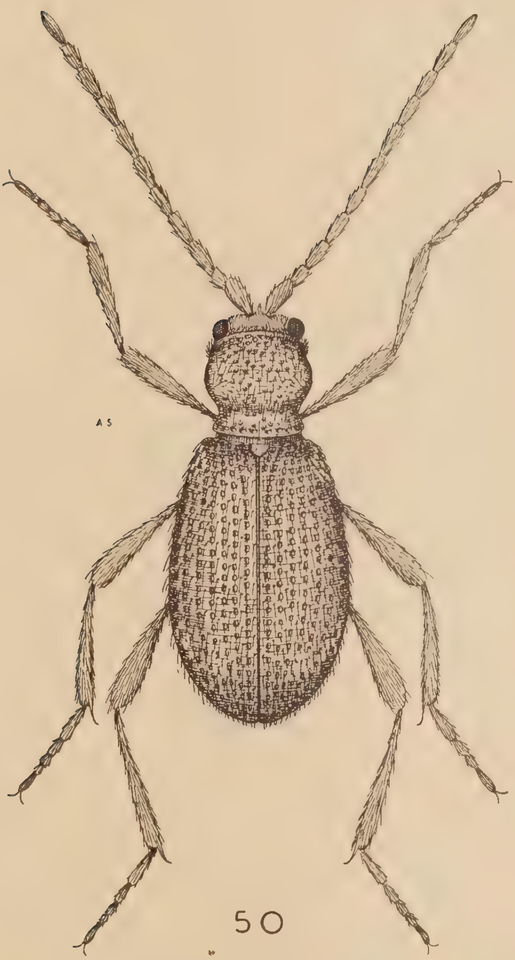


Fig. 50. *Ptinus pusillus*, Sturm, ♂.

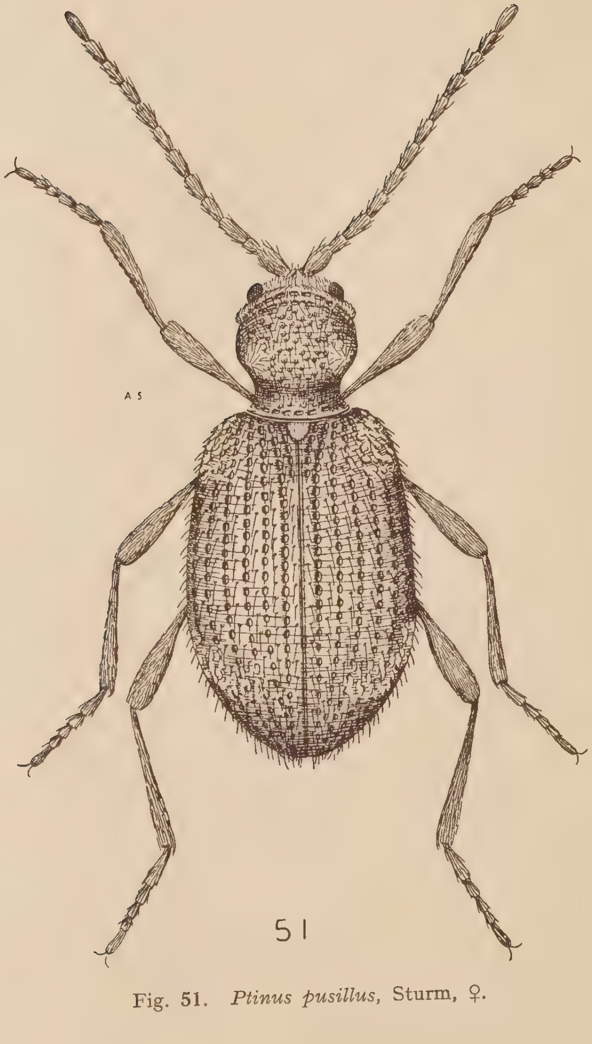


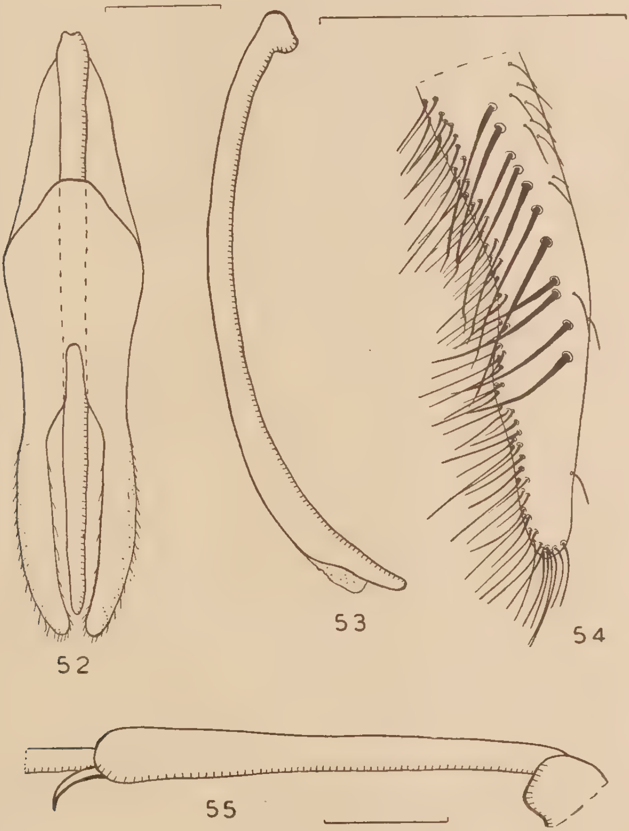
Fig. 51. *Ptinus pusillus*, Sturm, ♀.

and more oval ; (4) discal strial punctures of elytra generally only half as broad instead of as broad as to slightly broader than intervals ; (5) metasternum shorter ; and (6) legs slightly shorter and stouter, and middle and hind tibiae with apical spurs short and straight instead of very long and strongly curved.

Distribution. Widely distributed in Europe.

Comparative notes. It is closely related to *P. fur* with which it is often confused in collections, but may be easily distinguished as shown above.

Habits. It has been recorded from granaries (Boieldieu, 1856), on old seed-sacks in a granary (Joy, 1932), in a corn shop (Donisthorpe, 1906), and in a house in a rotten staircase (Blair, 1930).



Figs. 52–55. *Ptinus pusillus*, Sturm : (52) dorsal view of ♂ genitalia ; (53) right lateral view of median lobe ; (54) outer lateral side of apex of paramere ; (55) hind tibia of ♂.

Ptinus subpilosus, Sturm (figs. 56–58).

Ptinus subpilosus, Sturm, Deutschl. Ins. **12,** 1837, p. 82, t. 258, f. c.

♂. Length, 2·8–4·0 mm. ; breadth, 1·1–1·7 mm. Elongate, subparallel-sided ; cuticle brownish-testaceous. *Head* with a fine, median longitudinal impression on front ; moderately densely clothed with recumbent to suberect, testaceous hairs which are one-third to two-fifths as long as third antennal segment. Surface with front densely, microscopically asperate ; basal region and sides above eyes with very fine, dense, indistinct granules. *Pronotum* with shape and impressions as shown in fig. 56. Surface with round, low to prominent tubercles which are one-fourth to one-half coarser than facets of eyes and on basal half are separated by less than one to four diameters but on middle of disk are usually separated by one-half to one diameter ; with a single basal marginal row of deep, coarse (larger than tubercles), transversely oval punctures ; on anterior fifth of disk with similar but sparser and often nearly round punctures ; surface between coarse punctures and tubercles densely, microscopically asperate on basal third and elsewhere with numerous microscopic punctures. From each tubercle arises an erect, testaceous hair which is about one-half as long as third antennal segment. *Elytra* with erect hairs of intervals equal and usually one and a half times as long as strial punctures ; setae of strial punctures one to one and a half times as long as their punctures ; intervals with long, narrow (about five to six times as long as broad); recumbent, moderately sparse, white hairs which form two irregularly transverse bands on each elytron, one on basal fourth and one on apical fourth. Strial punctures on middle of disk deep, quadrate, as broad as intervals, and separated longitudinally by one-half to three-fifths their lengths. *Scutellum* densely clothed with pale-testaceous, recumbent to suberect hairs. *Metasternum* with median longitudinal line very broad (slightly broader than hind trochanter), deep, and confined to posterior half ; disk with posterior two-thirds strongly convex and anterior third strongly declivous ; disk with narrow (about two to three times as long as broad) punctures which are slightly narrower than to as coarse as facets of eyes and separated usually by two to three diameters ; sides of metasternum with punctures like those of disk but denser and slightly coarser. Abdomen with punctures of middle region of first three sternites long, narrow (about five to six times as long as broad), and separated by one to four diameters. Tarsi with apex of fourth segment not dilated. *Genitalia* (figs. 57–58) as figured.

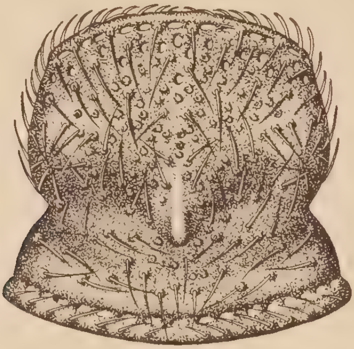


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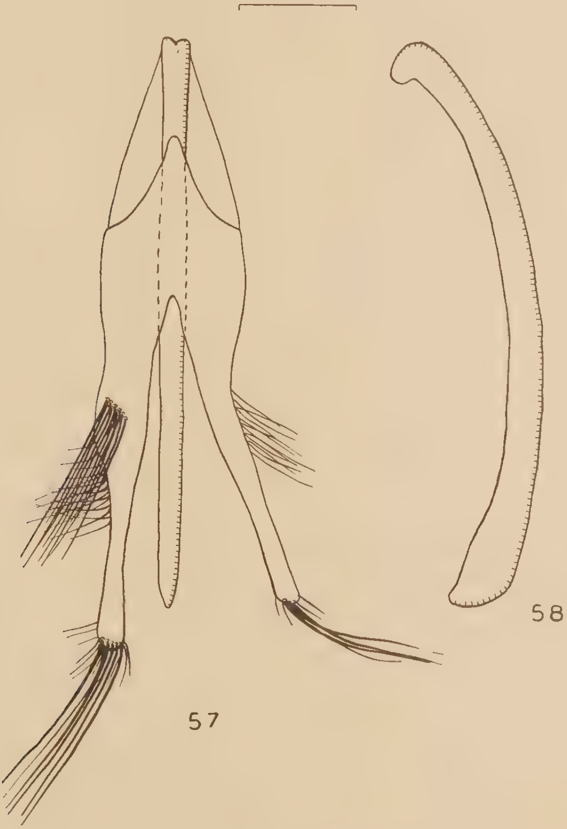
Fig. 56. *Ptinus subpilosus*, Sturm, ♂.

♀. May be distinguished from ♂ as follows : (1) eyes less convex and much smaller ; (2) antennae relatively shorter and with third segment about as short as second instead of twice as long ; (3) pronotum without a median gibbosity on basal third and with tubercles everywhere denser, being nearly as dense on basal third as on middle of disk ; (4) elytra obovate instead of subparallel ; (5) erect hairs of elytral intervals very unequal instead of equal, hairs of odd intervals often being two to three times as long as those of even intervals ; (6) discal strial punctures slightly sparser and, particularly in first stria, often separated longitudinally by one diameter ; (7) metasternum shorter and with median longitudinal line deep but relatively narrower than that of male and confined to posterior fourth ; (8) disk feebly convex instead of with posterior half very strongly convex ; (9) punctures of metasternal disk slightly coarser than facets of eyes and oval (usually one and a half times as long as broad) ; (10) punctures of middle region of first three abdominal sternites one and a half to three times as long as broad instead of being usually five to six times as long as broad ; and (11) legs relatively shorter and stouter.

Distribution. Europe.



Figs. 57–58. *Ptinus subpilosus*, Sturm : (57) dorsal view of ♂ genitalia ; (58) left lateral view of median lobe.

Comparative notes. The ♂ is similar to those of *P. hirtellus*, Sturm, and *P. latro*, F., but from both may be distinguished by the presence of white hairs on the elytra and the asymmetrical instead of symmetrical parameres. The ♀ resembles that of *P. pusillus*, Sturm, but may be easily distinguished by the very unequal instead of equal hairs of the elytral intervals.

Habits. It is found in rotten wood and sometimes in ant nests (Fowler, 1890). It once became a house pest in the Rheinland (Zacher, 1927 *a*).

Ptinus bicinctus, Sturm.

Ptinus bicinctus, Sturm, Deutschl. Ins. **12,** 1837, p. 57, t. 251, f. c.

♂. Length, 2·2–3·5 mm. Elongate, subparallel-sided; cuticle brownish-testaceous. *Head* with a fine, scarcely noticeable, median longitudinal impression on front; moderately densely clothed with recumbent to suberect, testaceous hairs which are a third to a half as long as third antennal segment. Surface with front densely, microscopically asperate; basal region and sides above eyes with dense, very fine, and indistinct granules. *Pronotum* feebly, transversely gibbous across middle and on each dorso-lateral side with a broad, low gibbosity. Surface with low, often very indistinct, round granules which are finer than to slightly coarser than facets of eyes and on basal and apical fifth are sparse and very indistinct, while on most of middle they are coarser, more distinct, and usually separated by less than one to one diameter; with a single basal marginal row of deep, coarse (nearly twice as large as facets of eyes), close punctures; on anterior fourth of disk with numerous similar punctures and on middle of disk with coarse punctures slightly finer and much less distinct; surface between tubercles and coarse punctures densely, microscopically asperate on basal and anterior fourth and elsewhere with numerous microscopic punctures. From each tubercle arises an erect to suberect, testaceous seta which is one-half to two-thirds as long as third antennal segment. *Elytra* with erect hairs of intervals more or less equal in length and usually about two to three times as long as discal punctures; setae of strial punctures two to two and a half times as long as their punctures; intervals with oval (about three times as long as broad), moderately long, recumbent, dense to sparse, white hairs which form two irregularly transverse and much interrupted bands on each elytron, one on basal fourth and the other on apical fourth. Strial punctures on middle of disk deep, subquadrate, one-half to three-fifths as broad as intervals, and separated longitudinally by one length. *Scutellum* densely clothed with short, recumbent, pale-testaceous hairs. *Metasternum* with median longitudinal line broad, moderately shallow, and confined to basal half; disk feebly convex and with long (one and a half to three times as long as broad) punctures which are finer than to as coarse as facets of eyes and are separated by less than one to, particularly posteriorly, four diameters; sides of metasternum punctate like disk but slightly more coarsely and densely so. Abdomen with middle region of first three sternites with very narrow (distinctly narrower than facets of eyes) and long (four to six times as long as broad) punctures which are usually separated by one to three diameters. Tarsi with apex of fourth segment not dilated. *Genitalia* with right paramere shorter than left and with hairs very similar to those figured for *P. subpilosus*, Sturm.

♀. May be distinguished from ♂ as follows: (1) eyes less convex and smaller; (2) antennae relatively shorter and with third segment only one-third longer than second instead of twice as long; (3) pronotum with tubercles usually slightly denser, particularly basally, and more prominent; (4) elytra obovate instead of subparallel-sided; (5) metasternum shorter and without a median longitudinal line; (6) metasternal disk flat instead of feebly convex; and (7) abdomen with punctures of middle region of first three sternites slightly broader and usually two to five instead of four to six times as long as broad.

Distribution. Europe, North Africa, North America.

Comparative notes. The ♂ is very close to that of *P. subpilosus*, Sturm, but may be distinguished by not having a distinct median gibbosity on basal third of pronotum and by the strial punctures of elytral disk which are one-half to three-fifths as broad as intervals instead of as broad. The ♀ closely resembles that of *P. pusillus*, Sturm, but may be distinguished by the elongate instead of round to feebly oval punctures of the middle region of the first two sternites.

Habits. It is found in old wooden barns (Reitter, 1911), granaries (Boieldieu, 1856, p. 287), and in warehouses and dwellings (Brown, 1940). It has been found breeding in bags of stored flour in Nebraska (Cotton & Good, 1937).

Ptinus villiger, Reitter (fig. 59).

Bruchus villiger, Reitter, Verh. Nat. Ver. Brünn **22,** 1884, p. 311.

♂. Length, 2·2–4·0 mm. Elongate, subparallel-sided; cuticle rufo-piceous. *Head* moderately densely clothed with recumbent to suberect, testaceous hairs which are one-third to three-fifths as long as third antennal segment. Surface densely, microscopically asperate on middle of front and elsewhere with dense, very fine indistinct granules. *Pronotum* with shape and impressions as shown in fig. 59.

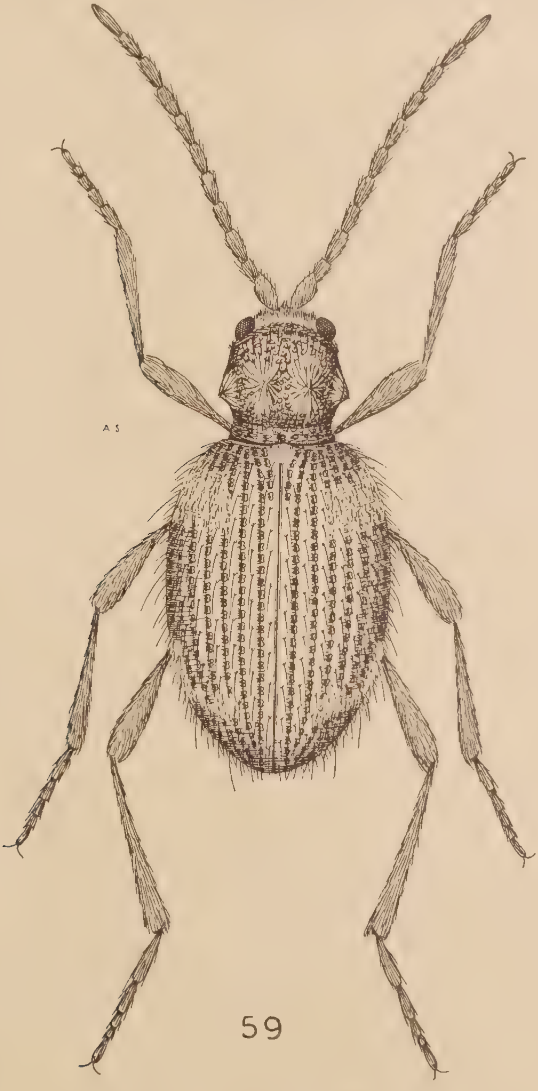


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Fig. 59. *Ptinus villiger*, Reitter, ♀.

Surface with round to irregularly shaped, low tubercles which are as coarse as to two times as coarse as facets of eyes and are contiguous to separated by one diameter ; with a single basal marginal row of deep, large (as large as coarser tubercles of pronotal disk), close punctures ; on anterior fourth of disk with a few sparser, less distinct, coarse punctures ; surface between coarse punctures and tubercles densely, microscopically asperate on basal and apical fifth and elsewhere with numerous microscopic punctures. From each tubercle arises an erect to suberect, testaceous seta which is one-half to two-thirds as long as third antennal segment. *Elytra* with erect hairs of intervals two to four times as long as strial punctures, those of odd intervals often being twice as long as those of even intervals ; setae of strial punctures two to three times as long as their punctures ; intervals with long, narrow (five to six times as long as broad), recumbent, moderately sparse to dense, white hairs which form two irregularly transverse and much interrupted bands on each elytron, one on about basal fourth and one near apical fourth. Strial punctures on middle of disk deep, quadrate, usually as broad as intervals, and separated longitudinally usually by slightly less than their diameters. *Scutellum* densely clothed with moderately short, recumbent to suberect, pale-testaceous hairs. *Metasternum* with median longitudinal line moderately deep, about as broad as fifth tarsal segment, and confined to posterior third ; disk with posterior half moderately convex ; punctures of disk nearly as broad as facets of eyes, two to three times as long as broad, and usually separated by one to three diameters ; sides of metasternum with similar but denser and coarser punctures. Abdomen with coarse punctures of middle region of first three sternites slightly narrower than facets of eyes, three to five times as long as broad, and separated usually by two to three diameters. Tarsi with apex of fourth segment not dilated. *Genitalia* with right paramere shorter than left and with hairs of parameres very similar to those of *P. subpilosus*, Sturm, and *P. bicinctus*, Sturm.

♀. May be distinguished from ♂ as follows : (1) eyes slightly smaller and less convex ; (2) antennae relatively shorter and with third segment only slightly longer instead of twice as long as second ; (3) elytra obovate instead of subparallel-sided ; (4) strial punctures of middle of elytral disk usually one-half to two-thirds as broad as intervals ; and (5) metasternum shorter, disk flat instead of having posterior half moderately convex, and punctures of disk more oval, less elongate.

Distribution. Europe, Asia, North America.

Comparative notes. The ♂ may be distinguished from all its close relatives by the long, erect, and very unequal hairs of the elytral intervals. The ♀ is very close to that of *P. subpilosus*, Sturm, but is larger and has the strial punctures of the middle of the elytral disk distinctly narrower instead of as broad as intervals.

Habits. It is found in houses, warehouses, and granaries and feeds on flour, farina, corn meal, stored wheat, etc. (Cotton & Good, 1937). Notes on the life-history are given by Curran (1925) and the various stages are described by Gray (1935 *a*).

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MELITTOMMA INSULARE, FAIRM. (COL. LYMEXYLONIDAE), A SERIOUS PEST OF COCONUT IN THE SEYCHELLES.

By Desmond Vesey-Fitzgerald.

(Plates XIV & XV.)

Introduction.

Melittomma insulare appears to have been first recognised as a pest in Seychelles about the year 1904. Since that date the late Director of Agriculture for the Colony, Mr. P. R. Dupont, has made frequent reference to the insect in the annual reports of the Department of Agriculture. To this investigator are due various practical suggestions and remedies for alleviating the damage caused. In spite of this advice little effective control has been achieved, and it is strange but true that many planters appear to be but slightly conscious of the damage that the insect causes. The habits and life-history of the insect have remained obscure and, in fact, so rarely is the adult beetle seen that it is no exaggeration to say that not a single planter in Seychelles can recognise the beetle which causes them such great loss. At the same time *Melittomma* is a pest of the first magnitude which, now that the Coccidae have been brought under control, is the chief limiting factor to successful coconut cultivation in the islands.

The genus *Melittomma* has a wide distribution. In Schenkling's catalogue eleven species are recorded from Tropical Africa, Tropical South America, Madagascar, Java, Sumatra, New Guinea and China. Three species were seen during the course of the present investigation. The first of these was *M. insulare* from Seychelles and the Sambirano district of north-western Madagascar, which includes the island of Nossi-Bé near by. The Seychelles and Madagascan specimens are indistinguishable in both larval and adult characters and also the habits are the same. The status of this insect as a pest in Madagascar is recorded below (p. 395). The second species seen in Madagascar has been determined by the Imperial Institute of Entomology as *M. africanum*, Thoms. Nothing is known about the biology of this species. Several specimens were collected around a light by M. G. Olsoufieff at Perinet railway station, which is situated in the middle of the east coast forest belt. It seems probable that the frequence of the *Melittomma* at this spot is accounted for by the presence of huge stacks of split logs destined as fuel for the railway. *M. africanum* occurs also in East Africa and specimens from districts north-east of Lake Victoria are preserved in the Coryndon Memorial Museum at Nairobi. The third species seen from Madagascar was also collected by M. G. Olsoufieff at Perinet. This species, only one specimen of which was available, is not represented in the British Museum collection but appears quite distinct from *M. africanum*.

In Seychelles *Melittomma* only occurs on a few of the islands of the granitic series. Scott (1926) places on record the occurrence of *Melittomma* on Desroches Island, in the Amirantes Archipelago, which is of coral origin. This record has not been confirmed during the course of the present investigation, even though the island was searched for any evidence of the pest.

Distribution in Seychelles.

The curious inter-island distribution of the insect in Seychelles is a direct result of the distribution of palms. Palm forests occur only on the islands of Mahé, together with the little islands round its coast, on Silhouette, Praslin and Curieuse. With the exception of Curieuse, these are the only islands upon which *Melittomma* has been found. Upon all the remaining islands of the group both palm forest relics and *Melittomma* are absent, although upon many of these, as for example, La Digue, Felicite, Sisters, Marianne and Aride, etc., coconut plantations are extensive. The absence of the insect on Curieuse is apparently explained by the fact that this island was largely covered in the past by a *Lodoicea-Deckenia* palmetum and neither of these palms are hosts of *Melittomma.* The same palmetum was also dominant on Praslin, but on this larger island *Stevensonia* and *Nephrosperma* were also well represented, and these two palms appear to be the primitive hosts of *Melittomma.* On Mahé and Silhouette, *Lodoicea* was absent and *Deckenia* restricted, but both *Stevensonia* and *Nephrosperma* were excessively abundant. It is on these islands that the *Melittomma* is most abundant at the present time.

Dupont suspected that the insect attacked the native palms but repeatedly pointed out that evidence of its presence was not forthcoming. His explanation of this apparent paradox was that the insect is confined to low elevations and that during recent times all the natural palm forests on the lower mountain slopes have been destroyed. The comparative rarity of *Melittomma* in native palms is an undoubted fact, but its supposed absence is certainly more apparent than real. In the first place, as was indicated above, four of the six native palm species, namely *Lodoicea, Deckenia, Verschaffeltia* and *Roscheria,* are not attacked. Secondly it is only comparatively young, soft-wooded specimens of the remaining two species, viz. : *Stevensonia* and *Nephrosperma,* which are attacked. When this point is realised it is not difficult to demonstrate the occurrence of *Melittomma* in wild palms.

Stevensonia is the most usual wild host of *Melittomma* and this palm is attacked in exactly the same way as the coconut. The bole of *Stevensonia* is rounded off at the bottom, and the roots which emerge from the subterranean bulb are normally slightly exposed at ground-level. The larvae gain access at this point and bore upwards into the stem. If the palm is a very young specimen, it may be killed, and in this case a typical 'dead-heart' indicates an infested plant. Older palms are more resistant and may become hollowed out, but eventually survive the attack. The wood of an old specimen is too hard for the larva to bore into, and so, at maturity, the palm is immune to attack.

Coconut plantations formed a secondary palmetum which replaced the endemic palm forests. The coconut, in addition, offered a highly suitable environment to the *Melittomma.* The bole of a coconut has exactly the same structure as that of *Stevensonia* and, from the view-point of the insect, possesses the advantages of greater size, more sappy wood, and a longer period before the wood becomes sufficiently hard to be resistant to attack. In these circumstances, the *Melittomma,* originally a rather rare insect limited to the young stages of only two species of wild palms, was enabled to thrive and become the major pest that it is to-day.

Description and Biology.

Egg.

The egg has the shape of a cylinder with rounded ends. It is four times as long as wide, the measurements being : length 1 mm. and width 0·25 mm. Colour creamy white. Texture shiny ; the chorion is ornamented with a few rather scattered and very shallow impressions.

The eggs are laid in irregular clusters totalling altogether upwards of one hundred. The whole mass is enveloped in a rather sticky moist substance. In captivity the females take advantage of any shelter in which to poke the eggs. The long extensible ovipositor enables the eggs to be deposited in quite small crevices. If wood dust or loose soil are provided the female burrows into this and lays the eggs several inches below the surface. Eggs laid unprotected in a container invariably fail to hatch. Incubation lasts eleven days.

Larva (fig. 1).

The morphology of the larva has been studied by Gahan (1908). The larvae upon emergence from the eggs remain clustered and quiescent for a short time. Later they undertake a free migration. Under experimental conditions the larvae have been kept alive and active in moist soil or wood dust without any food up to nine days. If the larvae are supplied with freshly cut roots during this period they readily bore into them. Entrance is effected by way of small ' pin-holes ' from which fine dust subsequently exudes.

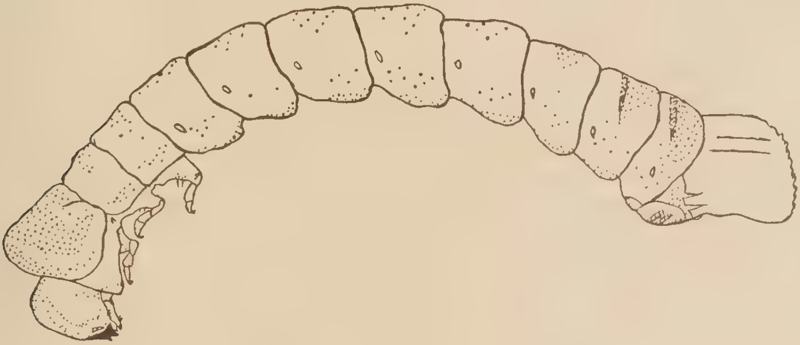

Fig. 1. Larva of *Melittomma insulare,* Fairm.

All parts of the roots are traversed, the root finally becoming honey-combed with borings and completely dry. Portions of roots experimentally buried in a depth of one foot in loose soil were reached by the larvae. Roots lying on the surface of the soil are freely entered by the larvae. Sometimes the larvae are noticed to climb about on the exposed root surface just like a free living insect larva. Survival under experimental conditions inside these cut roots is limited to the period during which the root remains fresh, but no doubt can exist that the larvae are nourished by the root tissue and further that it is by way of the roots that the larvae are enabled to enter the wood of the bole. The practical application of the above observations is of great importance. It is clear that in the first place there is no necessity for the female beetle to lay the eggs near to the tree, since the early wandering of the larvae may carry them a considerable distance and enable them to reach roots buried in a fairly considerable depth of loose soil.

Experimental infestation of trees has been attempted, the following methods being adopted. The adult beetles or newly hatched larvae in loose silt or wood dust were confined in small cages clamped against the tree. Two types of surface were presented, one a wound cut through the bark to the central wood at about 3 in. above ground-level, and the other the shaved surface of the root bulb below ground-level. The confined beetles usually laid eggs without any difficulty, and the young larvae bored into both types of surface. Subcortical wounds above ground-level very frequently become oozy and in these circumstances the larvae did not survive, but otherwise the results obtained from the limited number of experiments which have been carried out do not indicate any preference between a trunk wound or a root wound as a starting point.

Under natural conditions borings in the wood usually originate from the root collar at ground-level. The roots at this point die, but it is often difficult to decide whether the borings actually have passed through, and as a consequence killed the roots, or whether they have passed between the roots and entered and bruised the wood at the base of the roots and in this way caused the roots to die. From the root collar the borings extend upwards and inwards, for the most part traversing the pithy tissue between the hard fibres. The actual bore is surrounded by a zone of bruised and discoloured wood which may cover an area with a diameter of a farthing piece. The bruised tissues around adjacent bores very soon become contiguous, and the whole infested block of wood is killed as a consequence (Plate XIV, fig. 2). Since the hard fibres of the wood are less concentrated towards the centre than at the periphery of the trunk, the borings tend to work towards the centre. The exact course followed by the borings is dependent on the size of the bole, the softness of the wood, the twist of the fibres, and the number of larvae present. The bores are not usually very long, seldom, if ever, extending for more than one foot from the ' open ' to the ' feeding ' end. As the bored wood rots away behind the larvae, they ascend into the living wood further up the trunk. Except under quite abnormal circumstances however the borings are limited to the first two feet of the trunk. The exact reason why the height of the borings are thus limited is not fully understood. That the larvae are able to bore into the wood of the higher parts of the trunk is demonstrated by the fact that occasionally a fallen tree continues to live, and the trunk is sometimes attacked at one or more points where it is in contact with the ground. This observation would indicate that availability of access, *i.e.* the fact that the young larvae can only enter at ground-level, limits the borings to the lower part of the trunk. In some very severely attacked trees borings have been found to extend as far as six feet up the trunk. It is noticeable however that these high borings do not continue for the full length of six feet from top to bottom, but that they are in reality short bores arising from the bark some way up the trunk against which rubbish may have been piled and thus provided a way of entrance for the larvae. This observation would appear to indicate that the uninterrupted length of the actual tunnel is the factor of importance, and there is reason to suppose that the feeding larvae, from considerations of respiration, cannot go very far away from the open end of their tunnels.

The larvae are usually found feeding in groups, their borings radiating from foci of infestation at the collar. The number of larvae present in a tree is variable and depends largely on the age of the tree, as well as the state of the attack. Medium-aged to old trees that fell over in full bearing and have been split up yielded the following numbers of larvae :—0, 5, 8, 15, 30, 46, 80 and 125. The older the tree the harder is the wood and consequently the smaller the number of larvae present. Conversely young trees yield more larvae. Trees which remain standing but exhibit serious symptoms of *Melittomma* attack, such as pinched tops to their trunks or a general dwarfed appearance, do not usually at this late stage harbour many larvae. Boles of such trees which have been split up yielded the following numbers :—0, 1 adult, 3 larvae and 1 adult, 7, 16, 21 and 37 larvae, respectively. Infested trees which have been cut down and examined before permanent symptoms of attack have developed yield very variable numbers of larvae, since it depends entirely if the attack is incipient or severe, or if the beetles have emerged and the tree has not since been reinfested, thus the numbers of larvae recovered from such trees were 0, 1, 9, 15, 24. Sufficient trees in this stage have, however, not been examined to make these figures conclusive. Trees which die standing are severely infested, but of course the actual number of larvae recovered depends on how many have already hatched at the time of examination. Dying trees examined yielded the following numbers of larvae :—30, 60, 34 larvae and 45 adults, over a period of four months, and another tree yielded 224 adults during a similar period. The larvae are able to complete their development after the tree has fallen, and living larvae, pupae and emerging adults have been recovered from stumps 2–3 months after the date of fall. The feeding larvae are always found with their heads upwards, that is, towards the innermost end of the tunnel. The larva is, however, able to move freely both backwards and forwards inside the tunnel, and apparently it is quite a frequent proceeding for the larva to migrate down to the mouth of the tunnel. All loose dust is regularly cleared from the tunnel and ejected from the end, the appearance of this dust being the most usual way of diagnosing an attacked tree. The skin of the larva appears to be always changed near the mouth of the tunnel and the cast horny tails are always ejected from the open end. It is suggested that this scrupulous cleaning of the tunnel from all obstructions is of importance in connection with the larval air supply.

The time required for the development of the larva is extremely uncertain and difficult to study. After a tree has died, fallen, or been cut down, the wood remains sufficiently sappy for the larvae to feed in it during many months. Healthy full-grown larvae have been taken from cut coconut trunks four months after they have been protected from reinfestation. Among 33 larvae collected from a living trunk six and a half months after the eggs had been laid, some had the appearance of being nearly full-grown. Their average length was 13·3 mm., the largest measuring 19 mm., and the smallest 9 mm. In another experiment 53 larvae were recovered from a young tree with sappy wood eight and a half months after infestation. The average length of this batch was 16 mm. The wood of this tree was very sappy and larvae feeding under such conditions usually reach a very large size, certainly 25 mm. in length. Hence it must be presumed that these larvae still had several months growth before them. An examination of this tree was particularly instructive as regards the progress of *Melittomma* attack in a tree. During the eight months that the 53 larvae had been boring, they had reached only a distance of seven inches upwards and three inches inwards. This area of bored wood was bruised, but not yet rotten or breaking away to form a cavity. In a field observation such an attack would be classed as an incipient attack, and by comparison borings which leave behind them a cavity would represent over a year's continual work. From the evidence available therefore, it seems probable that *Melittomma* feeds as a larva for a period of about one year. The size of the larva is no guide to its degree of maturity, since this varies with the quality of the food supply, as is illustrated by the following experiment. Larvae were placed inside small, split blocks of coconut wood which were changed as soon as they became mouldy. Under these conditions the larvae survived for two months. The most frequent cause of death in these larvae was unsuccessful sloughing of the skin. Even if the block of wood became quite sodden with rot the larva was not killed, but larvae removed from the wood and confined in a box died in less than a day. Bores, single or branched, were of course limited to the dimensions of the block of wood, but when the larvae were feeding well they averaged about 1 cm. length a day. All frass and cast skins were pushed down to the end of the boring. Under these artificial conditions the larvae can only be said to have existed and not to have thrived. The absence of growth was illustrated by measuring the diameter of the "horny tail" of a confined larva during successive instars. On 6th July the diameter was 1·75 mm., on 30th July it was 1·5 mm., and on 25th August it was only 1·4 mm.

Pupa.

The pupa is white and naked. It is armed with numerous thorny spines which enable it to move about within the pupal chamber. These spines are distributed as follows :—There are two pairs on the head, one in the centre of each eye and two on the vertex ; there are several of various sizes round the periphery of the prothorax, those on the front margin being directed backwards and those on the hinder margin directed forwards ; on the hind margin of the dorsum of all the remaining segments there is a series of small spines (six in number on each of the abdominal segments) which are directed backwards on all the segments except on the 4th, 5th and 6th abdominal segments, where they are directed forwards. There is a single rather larger spine in the centre of each side of each abdominal segment. The last abdominal segment is armed below with two strong prong-like processes and on each side with a cushion-like pad beset with several small spines.

When the larva is full-fed it migrates towards the periphery or base of the bored wood, *i.e.* it now works outwards and downwards, and constructs a pupal chamber which has a rather larger diameter than that of the feeding galleries. The actual size depends on the size of the larva, but it is made sufficiently large to allow the pupa free movement for a short distance backwards and forwards. One end of the chamber is blocked with the cast larval skin and the other end with frass. A larva which is ready to pupate can always be recognised by the fact that it is lying with its head *outwards* as opposed to the head *upwards* position of the feeding larva. Also the larva just before pupation loses the power of moving its legs and wriggles from side to side like a pupa. The pupal period lasts for rather over a fortnight. Three days after pupation the eyes are pigmented, and in a further twelve days the wings and thorax are pigmented and the perfect insect is ready to emerge. The perfect insect remains within the pupal chamber for an indefinite period, probably amounting to more than a fortnight, before it makes its way to the exterior.

Adult.

The adult beetle is of a cinnamon-brown colour. The insect is elongate, the length being about five times as great as the width. The size is extremely variable and depends upon the feeding conditions during larval life. The males are usually smaller than the females, but while no male ever exceeds the maximum size of the female, some females are as small as the smallest male. Measurements for males are 6–12 mm. and for females 8–20 mm.

The head is usually held in a deflexed position, being wider than long and almost entirely covered by the large compound eyes, which are black and separated below by only a narrow suture. Above, a small triangular vertex forms the top of the head between the eyes. The antennae are serrate and are of medium length, the flagellum being nine-jointed. The mouth-parts are complete, although no food is taken during adult life. The clypeus is semicircular with a median cluster of bristles along its edge. The labium is truncate and bears a pair of conspicuous three-jointed palps. The maxilla is complete, the palp being four-jointed and simple in the female. In the male the second and third joints of the maxillary palps bear an appendage arising from their front margin, and the fourth joint is lamellate. The mandibles are strong with a tooth just before the tip. The legs are long and adapted to running. The wings are well developed but often proportionately small in some of the larger females, the venation being of the Cantharid type. The elytra are elongate, rather soft, and pilose on the upper surface. The ovipositor of the female consists of a long extensile tube which is evaginated during oviposition, the distal third being strengthened by four rods and the opening at the tip flanked by a pair of valves.

Males and females occur in about equal numbers. Two infested stumps which were kept covered and from which all emergences were recorded yielded in the first case 26 males and 19 females and in the second case 114 males and 110 females. Both sexes are nocturnal. The males are very active, take flight quickly and are frequent visitors to light at night. The females fly very little but are very active runners and often take short jumping flights rather like a cockroach. Adult males live about six days and the female survives only four days after emerging from the pupal chamber. No food is taken during adult life. Males copulate freely with the females as soon as the latter emerge. There appears to be no special mechanism by which a male identifies a female except by direct contact. Prior to the union of the sexes the male exhibits great excitement. Since the male is usually much smaller than the female the former is forced to undertake a kind of dance in order to arouse the latter. First the male mounts on the back of the female and buzzes its wings, and at the same time it runs along the elytra of the female until the antennae of the pair are in contact. Immediately afterwards the male slips backwards until the genitalia are in contact. This act may be repeated several times.

The number of eggs which a female may contain varies greatly according to the size of the individual. An average-sized female was found to contain 384 eggs in the ovaries, while a very small female contained only 18 eggs.

Nature and Incidence of Damage.

Melittomma is wide-spread and abundant throughout the coconut plantations of the islands upon which it occurs. The presence of the larvae in a tree can be diagnosed by the exudation of dust from the borings around the root collar at ground-level. The gnawing of the larva is also plainly audible, especially after the bole of the trunk has been tapped with a mallet. In the later stages of attack the dust is not easy to see, since it may then be falling inside the hollowed out cavity of the bole. This cavity in the bole of the trunk is, however, in itself a sure sign of present or past attack by *Melittomma*. In order to illustrate the prevalence of the pest on the two islands of Mahé and Praslin, the result of an examination of 42 samples of 50 trees from localities selected at random is summarised below :—

Percentage of trees attacked by *Melittomma*	0	1–25 per cent.	26–50 per cent.	51–75 per cent.	76–100 per cent.
Number of localities from which respective per cent. incidence was recorded	4	2	8	14	14

It will be seen that in only 6 cases was the incidence negligible or slight, *i.e.* below 25 per cent., but in 28 out of the 42 localities the incidence was high, *i.e.* above 50 per cent. Since the above sample counts were made in localities representative of all types of coconut land in the two islands, the prevalence of the pest is manifest. The damage caused, however, is not always commensurate with the incidence, since certain trees suffer more from the attack than others. The factors influencing the degree of damage caused will be discussed below. A general assessment of the damage, actual and potential, can best be illustrated diagramatically. Fig. 2 summarises the data from thirteen localities, seven of which were situated on hillsides of sedentary soil, three on plateaux of coral sand, and three on alluvial soil. The left-hand column for each locality represents the percentage of trees attacked by *Melittomma*. The centre column represents the percentage of trees in which the trunk and crown have become pinched and attenuated as a result of the attack. These trees may be considered as being permanently damaged and for economic purposes valueless. The right-hand column represents the percentage of trees in the sample which have hollowed out boles. These trees are potential losses only, because this type of injury may cause the tree to fall over in full bearing, but, on the other hand, if abundant adventitious roots can enter the soil from round the root collar, a hollow tree can continue in full bearing. The life of such trees may not even be shortened, since the attack of *Melittomma* will cease when all the wood of the bole has been eaten away and the tree will ultimately become free from the pest. In these circumstances the tree may be considered undamaged from the economic point of view. It should be noted that many trees represented in column 2 may also be hollow and so represented in column 3 as well. It is not therefore the sum of columns 2 and 3 which represents the loss to the planter. It is column 2 which represents the absolute loss and column 3 which represents the potential loss, and the latter, in actual fact, is seldom effective. A hollow bole is the normal final stage of an attack from *Melittomma*, hence the closer the number of trees which are hollow approaches the total number of trees attacked, the more advanced must the attack be considered. Consequently in samples where the number of hollow trees approximates the number of trees attacked, the closer will the number of trees recorded in column 2 as permanently damaged approximate the ultimate damage likely to be endured by this particular plantation.

A study of the diagram (fig. 2) illustrates certain factors which are very evident in the field. In the first place, the attacks on shallow hillside soils may be contrasted with those on deep coral sands and beds of alluvium. In the former the number of permanently damaged trees, *i.e.* column 2, almost always exceeds half the number attacked, *i.e.* column 1. The only striking exception is the Anse Marie Louise sample, but it will be noted that in this case the number of hollow trees is also low, and the explanation is evidently that the attack at this place was, at the time of sampling, in its earliest stages. On the sands and alluviums, on the other hand, the permanent damage, *i.e.* column 2, upon only one occasion exceeds half the incidence, *i.e.* column 1, and in most cases the figure is considerably lower. The single case of a high damage figure, *i.e.* the Anse Louise sample, is explained by the fact that the sample was taken on a very badly drained plateau where a high water-table in effect caused similar conditions to a shallow soil. It will be noted also that the permanent damage figure, *i.e.* column 2, is lower for the alluvial soils, although the incidence figure, *i.e.* column 1, is in general higher in the case of alluviums. This fact depends on the recuperative power possessed by the coconut palm, and it shows that, other things being equal, the resultant damage caused by the *Melittomma* is proportionate to the quality of the soil.

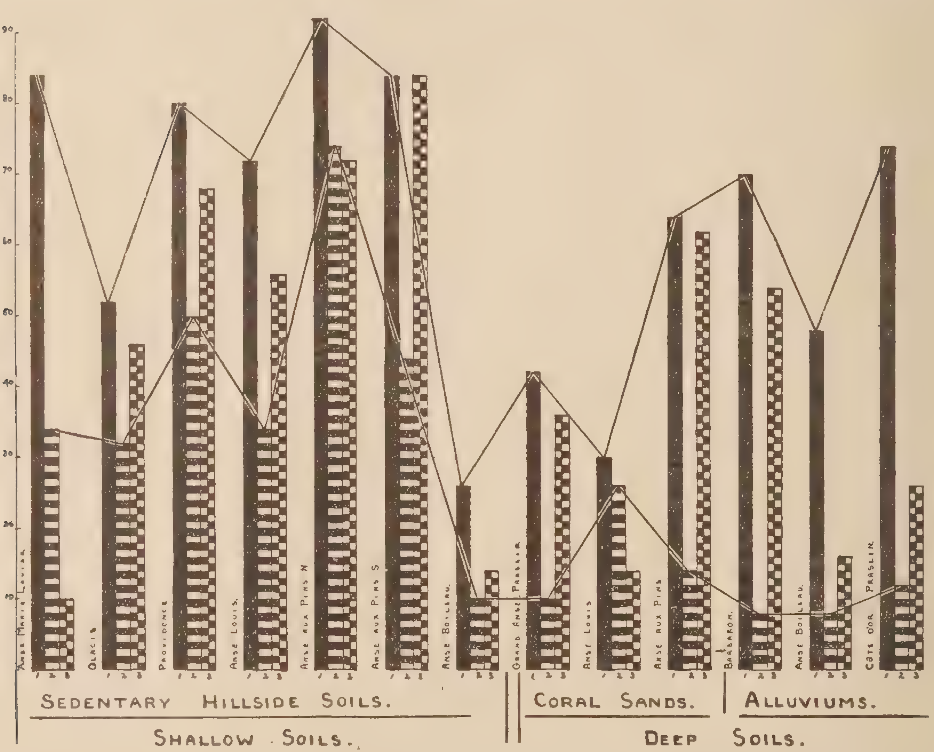

Fig. 2.

Considering each soil type separately, a higher incidence is noticeable on the granitic soils. On the sedentary soils of hillsides the incidence falls below 50 per cent.

in only one instance, and it is above 70 per cent. in five out of the seven samples. In the case of the alluviums, which are beds of granitic silt washed from the mountains, only one of the three samples has an incidence as low as 48 per cent. On the coral sand soil, however, the situation is reversed, in this case only one of the three samples being above 50 per cent., and even this outstanding example of a 64 per cent. incidence is lower than seven of the ten samples from granitic areas. On the other hand, even the lowest incidence of the three coral sand samples reaches 30 per cent., so it is not suggested that incidence is negligible on coral sand. It is, however, necessary to draw attention to the facts of the case because the fall of a tall plateau tree is of frequent occurrence, while hillside trees, which are smaller and not so top-heavy, fall less frequently. For this reason many planters consider *Melittomma* attack more severe on the flat lands, whereas in actual fact the reverse is the case. This misconception is enhanced by the fact that many planters fail to appreciate the symptoms of attack other than a fallen tree. The undersized, barren trees, with constricted trunks and small leaves, which are such a feature of the hillsides of Mahé, are not connected with *Melittomma* attack by planters, although they represent the greatest loss caused by this pest.

It has been pointed out that the quality of the soil is the factor which ultimately affects the welfare of the tree. It is, however, the attack of *Melittomma* which brings about the initial damage. This fact is very clearly illustrated by the graph superimposed upon the diagram. Upon the hillsides where the soil is poor, the degree of permanent damage, *i.e.* column 2, is in direct proportion to the incidence, *i.e.* column 1. It will be noted that a rise or fall in the incidence, represented by the top line of the graph, is followed by a corresponding rise or fall in the permanent damage, which is represented by the bottom line of the graph. This close correspondence between the number of attacked trees and the number of damaged trees is definite evidence that *Melittomma* is in fact the initial cause of the damage. Once this is realised the seriousness of the pest is evident. Upon the deeper coral sands and alluviums the damage caused is both actually and proportionally less, and there is no correspondence between the incidence and damage lines. This difference is to be explained by the recuperative power of the coconut palm, which in the congenial circumstances offered by a deeper soil obtains full scope. Since this recuperative power is of such great importance, and since it can and should be made use of as a means of alleviating *Melittomma* damage, the circumstances must be studied in greater detail. Passing therefore from a study of the cause and effect manifest under external conditions, the cause and effect inside different individual trees must next be considered.

The progress of the boring of *Melittomma* larvae in the bole of a coconut has been dealt with in another section of this paper. In general the incidence of *Melittomma* can be accepted as a fairly constant factor, and consequently the ultimate damage may be considered to depend on the two variable factors, *viz.* age of tree and soil. In order to see how practical use can be made of this conception it is instructive to examine the different types of damage in detail.

Type I. An old tree falls over in full bearing.

This form of loss is frequently encountered on the coastal plateaux and not infrequently on the hillside. To many planters this type of loss is the only one attributed to *Melittomma*. In this instance the tree will have been attacked by the larvae after the wood of the bole was of medium hardness. The progress of the boring will consequently have been comparatively slow, and the tree will have been able to compensate for the loss of its subterranean root bulb by an ample growth of adventitious roots from around the collar at ground-level or even from some little way up the trunk. The continuance of the boring will cause the entire centre of the bole to die, and later this dead wood is invariably attacked and consumed by the larvae of *Oryctes*. The result of the combined work of these two insects is to produce a conical central cavity which reaches to a height of some two feet up the centre of the trunk (Plate XIV, fig. 1). A tree past thirty years of age is quite able to live and thrive in this state, and it is an often noticed fact that the boring of *Melittomma* may even act as a stimulant and cause a heavy yield of nuts to be produced. The base of the trunk is however mechanically weakened and is unable to withstand an extra strain. A strong wind or an extra heavy crop of nuts is sufficient to cause the tree to fall over. By the time that the tree falls the *Melittomma* larvae may have finished all the wood which is suitable for their feeding. *Oryctes* larvae will, however, probably be abundant, feeding in the wood killed by the *Melittomma*, and for this reason blame for the loss is often attributed to the *Oryctes*. Should the tree not receive the extra strain necessary to make it fall, it may remain standing and, if the soil is of a reasonably good quality, in full bearing for an indefinite period. In this case first the *Melittomma* and then the *Oryctes* larvae will cease to feed in the tree, and in the end the palm will be free from these pests and become a " burnt-out case."

Type II. A young or medium-aged tree falls over in full bearing.

Although the result is the same as in the case above, the cause is different. It is easy to decide to which case any particular example belongs because, whereas the bole of an old tree is concave at the collar around which are many torn adventitious roots, the bole of a young or medium-aged tree is convex at the collar, and there will be few or only irregular adventitious roots. In the present instance the tree will have been attacked while the wood was sappy. The larvae in these circumstances are able to make rapid progress with their boring and, since the circumference of the bole of a coconut of this age often exceeds seven feet, the feeding larvae will have plenty of scope. The bores will extend inwards and upwards towards the centre of the bole, leaving some wood around the circumference of the collar at ground-level unattacked. Hence although the trunk of the tree, as a result of the borings, will become isolated from its subterranean " root bulb," a few roots will remain in contact with the trunk from around the collar. If the soil is of good quality even these few roots are able to nourish the tree, and consequently the crown of leaves will remain healthy and the crop of nuts will be maintained. The base of the trunk is, however, seriously weakened and, apart from the possibility of an extra strain, the continuance of the boring or even the later feeding of *Oryctes* may undermine the last supporting tissues and the tree will fall over. The trunk of a tree which has fallen over in these circumstances will often contain a hundred or more *Melittomma* larvae as well as *Oryctes* larvae. The former can complete their development in the fallen trunk and the latter find in it their optimum feeding conditions. Such fallen trunks should therefore be destroyed without delay.

Type III. The tree dies standing.

The symptoms of a tree dying from *Melittomma* attack are very characteristic. The crown of leaves starts to collapse from the outside inwards, *i.e.* the old leaves die first and the heart leaves often remain erect and green until the very last moment (Plate XIV, fig. 3 ; Plate XV, fig. 1). The leaves seldom fall from the tree, they simply collapse, often cracking across the petiole, and hang round the trunk. Any nuts on the tree cease to fill out and the spathes remain rigid and stick out among the drooping leaves. Owing to the fact that the leaf-crown becomes light and dry it is unusual for the tree to become top-heavy and fall ; it simply dies standing and the dry trunk remains erect long after the leaves have rotted away. The present case is very closely related to the last described, and it seems to be due only to a more concentrated attack of *Melittomma*, causing some fermentation in the living wood of the trunk, so that the vessels carrying nourishment to the leaves are severed before the base of the trunk is mechanically weakened. A tree that has died in these circumstances will contain up to several hundreds of full-fed larvae, and consequently if not immediately destroyed will act as a serious centre of infestation. Both type II and type III examples are typical of good quality soil. In type II the good soil has enabled the tree to survive to the last moment on the minimum number of roots. In type III the tree has made rapid and sappy growth in the rich soil and is therefore very acceptable to *Melittomma*. For this reason examples of these two types of loss are most usual in fertile ravines in the mountains. Owing to the fact that the beetles forsake dead and fallen trees for their living neighbours, this type of damage spreads, and if prompt measures are not taken, a whole ravine full of the very best trees will soon be lost (Plate XV, fig. 3).

Type IV. The trunk becomes constricted; the crown becomes more or less reduced, but although it remains a green colour, the yield of nuts is seriously impaired.

This type of damage, in its many forms, is the most widespread and therefore the most serious of all, yet few planters realise that the vast number of unthrifty trees which clutter up the majority of the estates in Mahé and Praslin are the direct result of *Melittomma* attack. A great number of coconut trees in the colony are not growing under optimum conditions. The soils on the steep hillsides are shallow and poor. The trees have consequently grown slowly and come into bearing late. The wood of such trees, even if they are still young, is as a result rather firm. *Melittomma* larvae make rather slow progress inside a trunk of this nature, and further, since the wood is dry, the larvae and the borings remain small. There is therefore at first a kind of balance set up. On the debit side is the *Melittomma* slowly eating away the wood of the bole ; on the credit side the tree has time continually to produce adventitious roots. It is inevitable in normal circumstances that the tree will ultimately lose in the struggle, because the more the *Melittomma* feeds, the less living " root bulb " will remain to nourish the tree, and the more adventitious roots are produced, the higher up the side of the bole must they originate and the further away from the soil will they be. The consequence of all this is that the top of the trunk tapers, the leaves become small and the crop is reduced (Plate XV, fig. 2). Ultimately the larvae will cease feeding, since the whole of the bole will have been bored and subsequently hollowed out by *Oryctes*. The tree will, however, have been permanently damaged, and while the few remaining living roots will gain sufficient nourishment to keep the tree alive, no active regrowth will be possible save in the exceptional circumstances of earth or rubbish becoming piled round the trunk. In such circumstances a fresh growth of adventitious roots will have a chance of entering a fertile medium, and the tree will be able to start growing again, the trunk will swell out to a normal size, and even a fair crop of nuts will be produced. Although it would seldom be worth the time and expense to rejuvenate seriously injured trees, this observation does point the way to a possible method of saving trees suffering from this type of damage. It must be remembered that once a coconut trunk has become constricted this part can never swell out ; hence this point will always remain a weakness, and if a heavy crown of leaves is produced at a subsequent date the trunk may crack at this point. On the other hand, trees which already show advanced symptoms of this type do not constitute a very serious source of infestation, since at this stage the *Melittomma* will have departed from the palm in the majority of cases, and their number would hardly justify the expense incurred in their destruction.

Associated Insects.

The *Melittomma* paves the way for a variety of other insects, but these are not serious pests by themselves and do not affect the issue. It may, however, be of interest to record them here.

Oryctes monoceros, Ol.

The association of this insect with *Melittomma* has already been indicated. Diseased boles of living trees and dead trunks of fallen trees constitute one of the more important breeding places of the beetle. The adult itself is not a very serious pest in Seychelles except to young plantations, the trees of which receive repeated set-backs from the attacks of the adult beetles on the crown. The control of *Melittomma* would certainly reduce the incidence of this pest, but cinnamon-leaf refuse-heaps would remain among the most dangerous breeding places for *Oryctes* larvae.

Diocalandra frumenti, F.

The larvae of this weevil feed in the wood immediately under the bark where it has been bruised by *Melittomma* boring. They make tortuous feeding galleries through the fermenting tissue. When full-fed the larva constructs a pupal chamber of ample dimensions which it packs round with torn fibres. The pupal period lasts about eleven days.

Coptotermes truncatus, Wasm.

The galleries of this termite are sometimes found filling the bruised wood of the bole of a coconut trunk attacked by *Melittomma*, and upon occasions they extend into the living tissue beyond the *Melittomma* borings.

Kalotermes (*Neotermes*) *laticollis*, Holmgr.

This termite is a rather rare associate of *Melittomma*, but its attacks on coconuts always appear to be secondary to the latter, although in other trees it may be a primary cause of damage to living tissue. The galleries form a central core of infested wood, the whole becoming transformed into a moist mass of chocolate-coloured mud-like substance. When dry this substance breaks down into a fine powder. The living wood is attacked by the termites, which drive their galleries up the stem into the pulpy part of the wood. The fibres of the wood are more resistant to their attack, but eventually the whole becomes broken down into the mud-like substance mentioned above. In the course of time the termite advances beyond the zone of *Melittomma* borings, and in these circumstances their work may hasten, or even actually cause, the fall of the tree.

Nasutitermes nigrita, Wasm.

This termite is responsible for the common ' nigger-head ' termitaria which are found on coconut trunks. This species feeds only on superficial dead and dry wood and may be associated with any type of injury or wound besides *Melittomma* attack.

Microcerotermes subtilis, Wasm.

This termite forms carton nests on coconut trunks, but feeds only on dead wood. It is especially common amongst the mass of dry adventitious roots emerging from under cracked flanges of bark round the base of the bole, which are so characteristic of old trees attacked by *Melittomma*.

Odontomachus haematoda, L.

This ant is very prevalent throughout the coconut plantations of the Colony. The nests are situated at the base of the bole slightly below the ground-level, under rubbish mixed with earth, or inside cavities of the root collar. During the day the ants remain hidden with their cocoons, but at night the workers roam about over the ground and seek their prey. The constant presence of such a fierce predacious ant at the very point where the tree is attacked by *Melittomma* might be expected to act as an efficient guard against this beetle. The ant seizes and mutilates the adult beetles with great avidity. However, a long series of records show that an abundance of ants is correlated with a high incidence of *Melittomma*. The only explanation which can be offered for this apparent paradox is that the excavations of the ant and the consequent loosening of the soil around the bole of the palm provide a free means of access for the newly hatched *Melittomma* larvae, which are themselves too small for the attention of the ant.

Control Measures.

(1) *Biological control.*

No known enemy of *Melittomma* exists in Seychelles except entirely casual predators of the adults and any accidentally exposed larvae. A visit was therefore made to Madagascar for a few weeks early in 1939 in order to search for possible predators and parasites. *Melittomma* was found to be an extremely serious pest of coconuts in the Sambirano district and on the island of Nossi-Bé near by in the N.W. corner of Madagascar. Owing to the pest, coconut plantations were being abandoned and other crops planted in their place. Infested trees were therefore plentiful, and permission was freely given to cut these down. The larvae were extracted by splitting up the boles, and later each one was dissected. No sign of any predator or parasite was found, and it was evident that nothing was holding the pest in check in the district. It is certain, therefore, that no effective parasite of *M. insulare* exists. It is possible that other species of *Melittomma* are parasitised, but it is most unlikely that such a parasite would be of any use against the present species. Biological control must therefore be considered impracticable.

(2) *Cultural alleviation.*

The various ways in which cultural methods may alleviate the effects of *Melittomma* attack have already been indicated in the discussion of the various forms of attack. The walling and earthing up of trees is a practice of long standing in Seychelles and has much to recommend it. The primary object aimed at is to cover the bole at ground-level so that no superficial roots are exposed for the female to lay her eggs on. If the earth is replenished as soon as wash takes place and if it is kept fairly compact round the bole, this end may be achieved. However, in practice, the earth gets washed away, so that the roots are soon re-exposed, and further, the beetle and larva are quite able to burrow through loose soil. While prevention of attack is therefore seldom achieved, an infested tree benefits greatly by having the bole earthed up so that new adventitious roots can enter the soil and gain nourishment for the tree. In order that full benefit may be obtained the work should be done properly. An ample amount of earth should be banked around the tree, and if this is situated on a steep slope a dry retaining wall of stones should be built ; the wall must not, however, be placed too close to the tree, and the roots must be given ample scope to pass through a good body of soil into the ground below. An insufficient amount of soil round the bole will only help to draw out roots which will eventually die, and in the end the tree will be perched up on a little mound and the chances of its falling will be increased. Trees which are well cared for in this way stand a very good chance of eventually recovering from an attack and continuing to bear fruit. Even unattacked trees growing on steep hillsides liable to soil wash benefit from this treatment.

(3) *Surgical treatment.*

It has been a common practice in the past to gouge out the infested wood from the bole of the tree, and if the tree was over thirty years old, this treatment was often successful. The wood of older trees is hard and so the wound does not ferment but dries up, and also at this age a well-established ring of adventitious roots from the bole at ground-level compensates for the loss of the subterranean root bulb. The work, however, was badly done in the past. Unskilled labourers were instructed to gouge out a certain number of trees each day, and so every tree was operated upon regardless of the presence or absence of *Melittomma*. In this way many healthy trees were unnecessarily damaged. If the work is set about in an intelligent way, most trees can be saved as long as the attack is not too advanced or the tree too young. It is advisable in the first place to decide to which class of attack each particular tree belongs. Young trees should be cut as little as possible and free drainage of the wounds should always be allowed for. Old trees, which are becoming hollow, should be cut as little as possible round the collar of adventitious roots, since this collar is the tree's only means of support. All cut surfaces should be immediately painted over with tar.

A more satisfactory method of treatment has been worked out as follows. The bole should be cleaned round so that all points at which borings enter are clearly visible. Each of these foci of attack should then be shaved with a sharp hatchet. The object to be aimed at is to make a clean section across the ends of the borings and *not* to cut out all the bored wood, since such an operation is often a lengthy and rather drastic undertaking. When the ends of all the bores are exposed the surface should be tarred over. The effect of the tar, besides being an antiseptic to the wound, is to close the ends of the borings. The larvae up in the trunk immediately come down to unblock the end of the bore, and in this way they become covered with tar and are killed. After this treatment the tree should be inspected at least three times at monthly intervals, and if any fresh signs of boring are apparent a new application of tar should be given in order to draw out the remaining larvae. A certain amount of bleeding will take place from the bored part of the wood, and of course the bruised tissue will die and eventually rot away and leave a cavity. But this will not incapacitate the tree, and at the end of the three month period the trees will be free from *Melittomma* larvae and also the wounds will be dry and hard. The cured tree should then be earthed up in the way described in the last section, and it is very probable that no further attention will be required.

(4) *Fumigation treatment.*

The main objections to the foregoing treatment are the time, trouble and money which have to be expended in order to obtain success. The fumigation method was therefore devised in order to simplify the work, so that ordinary labourers with the minimum of supervision can carry it out. The area of the plantation which is to be treated should first of all be marked out, and the labourers should be sent in with orders to clean round each tree and to prepare at its side a heap of soil ready to be used for earthing up the bole. A responsible person must then go round the trees with the fumigant. First, he must decide if the bores are only entering from the collar or if the tree is hollow. In the former case the fumigant is sprinkled freely round the bole, especially where the borings are visible. If the tree is hollow, the fumigant is simply placed inside the cavity. As soon as the treatment has been administered, a labourer, who is standing by, throws the prepared earth against the tree and packs it well down. If the slope demands a retaining wall for the earth this must be arranged.

By this method the *Melittomma* larvae, which, as has been explained in another section, always seek their air supply from the mouth of their boring, should be poisoned. At the same time *Oryctes* larvae are destroyed inside the hollow boles. The earthing up not only helps to retain the fumes round the openings of the borings but also stimulates the growth of fresh roots and so hastens the recovery of the tree.

As regard the best fumigant to employ, further experiments are necessary. It is greatly regretted that a supply of paradichlorobenzene, which is the most promising material, was unobtainable until after the close of this investigation. The method was, however, worked out with "cyanogas." The only grade of this chemical that was obtainable was the fine "A-dust," which is the least suitable for this work. The coarse grade known as "cyanogas flakes" would probably be much more suitable. In spite of the handicap imposed on the work by this lack of suitable material the method shows great promise of success at a very reasonable cost of money and effort, and therefore it can be recommended with confidence.

(5) *Prevention of spread.*

It is of common belief in Seychelles that the *Melittomma* was accidentally brought from Madagascar at the end of the last century in cattle fodder. However, it is evident from the foregoing account that such a happening is most improbable, both on account of the ecological relations of the insect in the islands and on account of the impossibility for such a short-lived insect in the adult state being able to survive such a voyage. It is, in fact, extremely doubtful if the beetle has even been able to spread from island to island within the Seychelles, and its present distribution is in all probability a relic of former land connections between the islands. However, the *Melittomma*-infested island of Praslin and the *Melittomma*-free island of La Digue are only separated by a channel three miles wide. The danger of the pest crossing to La Digue is therefore apparent. It seems that such a crossing would be no difficulty to a male beetle, but a gravid female would certainly be unable to fly so far. Theoretically, a light undersized female might easily accomplish the crossing and carry with her a few eggs ready to be laid. The non-establishment of *Melittomma* in La Digue indicates, however, that such a migration has never occurred. The possibility of accidental distribution aided by man must therefore be considered. The only way that this might take place seems to be if split logs from *Melittomma* infested trees were shipped from Praslin to La Digue for some purpose such as lime burning. Transportation of coconut wood should therefore be prohibited from the *Melittomma*-infested islands.

(6) *Sanitary measures.*

This last means of attack should be compulsory, for if one planter harbours serious infestations of *Melittomma* his neighbours are sure to suffer in time. Dying trees should be rooted out and their boles destroyed with fire. Concentrations of the pest in ravines should be dealt with drastically. It is not difficult to see when trees are past saving, and it is a short-sighted policy to leave a tree which is riddled with *Melittomma*, even though it may give a few more nuts during the next month or two. It is much better in these circumstances to cut out all the infested trees, burn their roots and the lowest two feet of the trunk, and replant the area. The boles of young and medium-aged trees which have fallen over should be split so that the wood can dry. Later the dry logs can be burnt. The destruction of old trees which have fallen over and trees which show the symptoms enumerated above under type IV damage, while not so necessary, cannot fail to be anything but beneficial. It is suggested that if planters are negligent over taking these precautions, inspectors should locate centres of infestation on estates and notify the owners that action is necessary.

Summary.

1. *Melittomma insulare* is a serious pest of coconuts in parts of Seychelles and Madagascar.

2. In Seychelles the insect is only known from a few of the islands, its distribution being dependent on the original distribution of its primitive host-plants which are two species of endemic palms.

3. The eggs are laid under cover in batches and hatch in eleven days. The larvae feed in galleries in the base of the trunk for an indefinite period depending on the sappiness of the wood. Pupation takes place in the enlarged end of a boring. The adult is nocturnal and short-lived.

4. The damage caused depends on the age and situation of the tree which is attacked. Other things being equal trees growing on good soils are damaged least.

5. Several other species of insects are associated with *Melittomma*, but all are of minor importance.

6. Remedial measures suggested comprise :—(*a*) Cultural, by earthing up the base of the trunk ; (*b*) surgical, by incising attacked wood and tarring over the wound ; (*c*) application of a fumigant at the source of the larval air supply ; (*d*) sanitary measures designed to destroy the major breeding centres.

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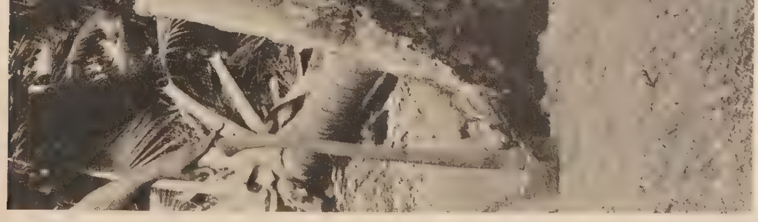
EXPLANATION OF PLATE XIV.

Fig. 1.—Section of the base of a trunk of coconut showing *Melittomma* borings extending into the living tissue at the apex of the central core of dead wood. The larger honeycomb cavities in the body of the dead core are caused by *Oryctes* larvae which feed in the wood after it has been killed by *Melittomma* larvae. This photograph shows how a central cavity is produced as a result of the work of these two insects, while at the same time living wood extends down to ground-level around the perimeter of the bole. From this perimeter adventitious roots are able to enter the soil.

Fig. 2.—Transverse section of coconut stump showing *Melittomma* borings in the sappy tissue between the wood fibres. Each bore is surrounded by a zone of bruised tissue, and these zones eventually join up causing a large block of dead wood.

Fig. 3.—Early symptoms of severe *Melittomma* incidence. The lower leaves have collapsed and are hanging round the trunk. The spathes, bearing attenuated nuts, are seen projecting after the supporting petiole has drooped. Nothing can save such a tree, which will eventually die standing (see Plate XV, fig. 1).



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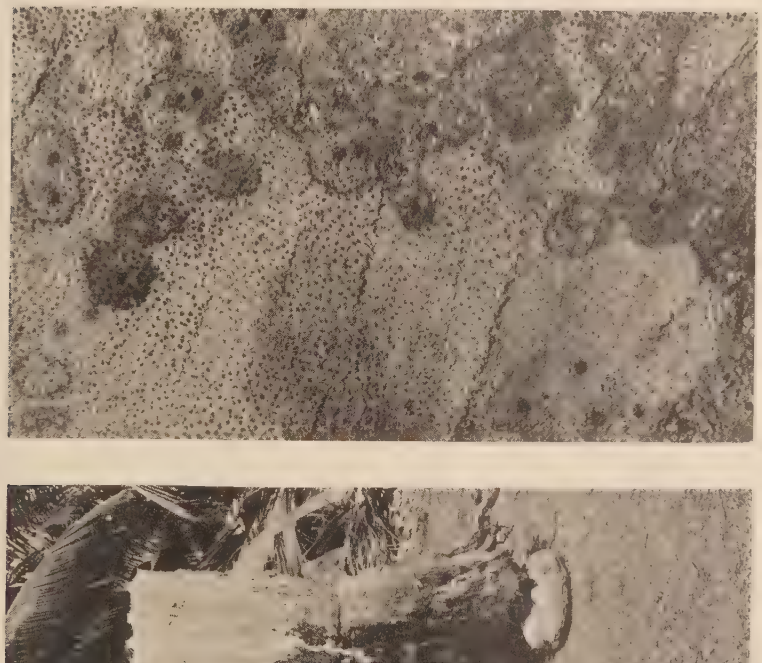


Fig. 2.

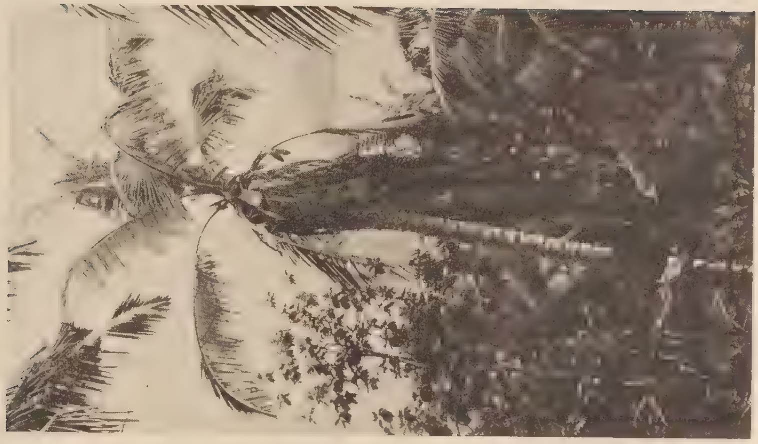


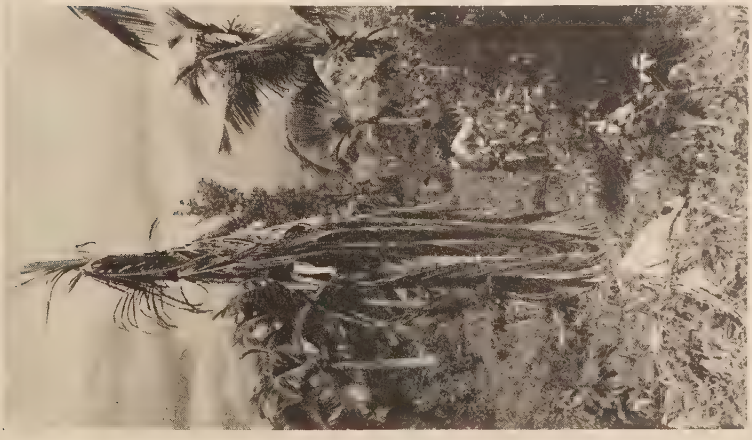
Fig. 3.

EXPLANATION OF PLATE XV.

Fig. 1.—Later symptoms of severe *Melittomma* incidence. All but the heart-leaves have collapsed and very soon the tree will be dead. In this stage large numbers of beetles will be emerging and forsaking the doomed tree in favour of its more healthy neighbours.

Fig. 2.—A tree growing on poor soil showing characteristic symptoms of chronic *Melittomma* incidence. The tree in this picture has never been able to develop fully. The trunk has tapered and become barren but is too light to cause the tree to overbalance. On the other hand, owing to the very slow growth, the wood of the trunk is dry and so the beetle larvae are only able to feed slowly in small numbers. Consequently the tree does not die as a result of the attack.

Fig. 3.—Full-bearing coconuts which have fallen over as a result of *Melittomma* attack. The palms in this photograph are first class trees growing on good soil. *Melittomma* has however bred unchecked, vacating fallen trunks for their healthy neighbours. As a consequence trees are falling in an ever extending area and the continuity of the plantation is destroyed.



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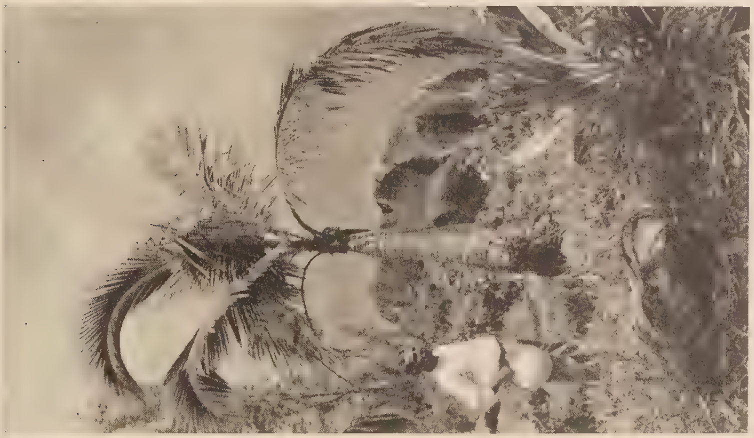

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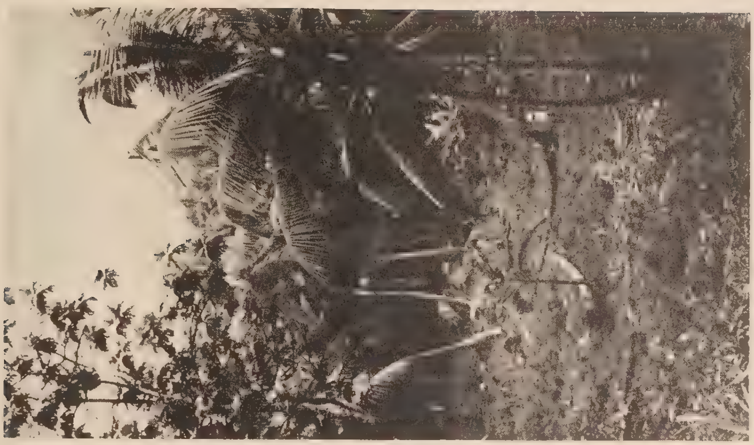

Fig. 3.

NEW INJURIOUS CURCULIONIDAE (COL.).

By Sir Guy A. K. Marshall.

The types of the following new species will be deposited in the British Museum.

Protostrophus avidus, sp. n.

♂♀. Derm black, with dense sandy grey scaling, the elytra with a small brown spot at the base of the suture and often some indefinite brownish markings elsewhere; underside grey.

Head separated from the rostrum by a curved furrow which reaches the side margins, but the lateral portions normally hidden by scaling; forehead flat, with a deep median sulcus and suberect spatulate setae; eyes moderately convex, produced backwards for about one-third of their length, the orbit forming a sharp angle posteriorly. *Rostrum* (without mandibles) transverse (5 : 8), the apex five-eighths the width of the base, the sides almost straight; the dorsum quite flat, with a low median carina. *Antennae* red-brown; funicle with joint 1 twice as long as 2, 3–7 a little longer than broad. *Prothorax* transverse (2 : 3), moderately rounded laterally, widest slightly behind the middle, not constricted at the apex, the basal angles rounded the apical margin truncate; dorsum moderately convex longitudinally, the sculpture hidden by the dense scaling, except for minute black dots bearing the recumbent spatulate setae and a narrow flattened punctulate median carina, which widens beyond the middle but does not reach the apex. *Elytra* ovate, broader in ♀, widest at about the middle, shallowly sinuate at the base, broadly rounded behind, the dorsal outline feebly convex; the punctures in the shallow striae partly hidden by scaling and but little smaller behind; the broad flat intervals with a row of numerous recumbent setae, which are sometimes rather irregular posteriorly, the scales small, round and contiguous. *Legs* black, with the tarsi red-brown, densely squamose; front tibiae with the apical row of spines continuing round to the external margin, hind corbels bare.

Length 4·0–4·6 mm., breadth 2·0–2·5 mm.

TRANSVAAL: Rubbervale, 3♂♂ 5♀♀, i.1939 (*L. Parris*).

Reported by the Division of Entomology, Pretoria, as attacking young citrus leaves.

Most nearly allied to *P. amplicollis*, Fhs., which has, however, a very differently shaped prothorax, which is constricted at the apex and very deeply so at the base, and the median carina is replaced by a fine abbreviated stria; the eyes are flatter and less produced backwards, and the tibiae are stouter.

Protostrophus salignae, sp. n.

♂♀. Derm black, with fairly dense grey scaling, which is much more sparse (perhaps abraded) on the anterior half of the body, the lateral intervals of the elytra beyond stria 7 bare and shiny; underside with sparse grey scales, without any dense patch at the sides of the metasternum.

Head separated from the rostrum by a short deep sulcus, the length of which is only half the width of the base of the rostrum; forehead coarsely punctate with a broad deep median sulcus; eyes rather strongly produced backwards, deepest a little behind the middle, the orbit not projecting on the posterior edge. *Rostrum* (without mandibles) much shorter than its basal width (7 : 11), coarsely and closely punctate, with a low median carina, the base of which projects slightly into the transverse basal sulcus, and a shallow transverse depression near the apex. *Antennae* piceous black ; funicle with joint 1 much longer than 2, 4 to 6 a little longer than broad. *Prothorax* transverse (4 : 5·5), moderately rounded laterally, widest at a little behind the middle, very narrowly and shallowly constricted at base and apex, which are both truncate and of equal width, the basal angles not prominent ; dorsum gently convex longitudinally, with comparatively small isolated punctures on the disk, the interspaces finely punctulate, and with a narrow impunctate median line from the base to five-sixths, the punctures becoming denser and more rugose laterally ; the setae appressed, scale-like and inconspicuous. *Elytra* ovate, a little broader in ♀, widest at about the middle, obtusely acuminate behind, subtruncate at the base, the dorsal outline almost flat from the base to beyond the middle ; the shallow striae with small separated punctures which become much smaller behind, not hidden by scaling ; the intervals broad and flat, with a row of short appressed setae, the scales small, round and contiguous. *Legs* black, with dense grey scaling ; front tibiae with a regular close row of spines at the apex, the hind corbels bare.

Length 4–5 mm., breadth 1·7–2·2 mm.

ZULULAND : Kwambonambi, 3♂♂ 5♀♀, iii.1926 (*P. M. Rattray*).

Recorded by the Division of Entomology, Pretoria, as attacking seedlings of *Eucalyptus saligna*.

Belongs to the group of *P. ambiguus*, Fhs., and *sparsus*, Fhs., but most nearly allied to *vastator*, Mshl. (Bull. Ent. Res. **17**, 1927, pl. xix, figs. 4, 9), from the Transvaal. *P. vastator* is a larger species, with more acuminate elytra ; the rostrum is much longer, more narrowed apically, with a much more prominent median carina and the basal sulcus almost reaching the lateral margins ; the prothorax is much more convex ongitudinally, with the base lower than the apex and more constricted, etc.

Systates hargreavesi, sp. n.

♂♀. Derm black, with sparse minute setiform grey scales and small patches of broader oval pale scales with a coppery reflection ; pronotum with an ill-defined broad lateral stripe of coppery scales on each side (often abraded) ; elytra with scattered groups of coppery scales, occasionally forming rows of distant ill-defined spots on intervals 3, 5, 7 ; underside with sparse pale setae and with coppery scales at the sides of the sternum and basal ventrites.

Head separated from the rostrum by a curved sulcus, obsoletely wrinkled, with sparse narrow pale scales ; forehead flat, wider than the dorsal area of the rostrum, with a deep median sulcus ; eyes moderately convex, projecting laterally beyond the temples, highest at the middle. *Rostrum* as long as broad (♀) or a little longer than broad (♂), parallel-sided in the basal half, then widening slightly at the genae ; the dorsal area flat, not declivous at the apex, parallel-sided basally and gradually widening apically, obsoletely rugulose, carinate laterally, with a distinct low median carina which bifurcates in front, though the branches are almost obliterated, the epistomal margin low, semi-circular. *Antennae* elongate, black or piceous, scape almost straight, cylindrical, abruptly clavate at the apex, with short pale recumbent setae ; funicle with joint 1 as long as or slightly longer than 2 and 3, 7 longer than 6. *Prothorax* transverse (4 : 5), rounded laterally, widest behind the middle, without any sub-basal lateral projection, truncate at base and apex, the latter being rather narrower ; the dorsum feebly convex longitudinally, with low shiny separated granules, each bearing a short erect seta, and a much flattened (sometimes almost obliterated) broad ill-defined rugulose median carina, which is often obsolete on the basal half, and with sparse short setiform scales in the interstices. *Elytra* narrowly elliptical in ♂, wider in ♀, widest at about the middle, somewhat produced downwards at the apex in ♀, constricted close behind the base, the carinate basal margin broadly sinuate, the lateral angles produced into a granular process which varies a good deal in shape and is very similar in the two sexes ; the broad shallow striae containing large subquadrate punctures, the septa between which usually consist of low granules ; the intervals about as wide as the striae, slightly convex, with a row of low separated granules which are more evident near the base and on the declivity and bear short erect setae. *Legs* black, with sparse pale setiform scales ; all the tibiae of ♂ with a fringe of long curled pale hairs on the inner face, the hind pair very strongly curved in the middle, the apical half of the inner face smooth, shiny and impunctate, the outer apical angle rather less produced than in other species of the group ; hind tibiae of ♀ simple but denticulate internally.

Length 7·2–9·0 mm., breadth 3–4 mm.

UGANDA : W. shore of Victoria Nyanza, Buddu, 1♀, ix. 1911 ; Daro Forest, Toro, 4,000–4,500 ft., 8♂♂ 5♀♀, x. 1911 (type) ; Mbarara-Fort Portal road, S. Toro, 3,800–4,200 ft., 1♂, x. 1911 ; W. Ankole, 4,500–5,000 ft., 1♂, x. 1911 ; Mpanga Forest, Toro, 4,800 ft., 1♀, xi. 1911 ; Ungusi R., Unyoro, 3,000–3,400 ft., 1♂, xi. 1911 ; Bugoma Forest, Unyoro, 3,700 ft., 1♀, xii. 1911 ; near Hoima, Unyoro, 3,700 ft., 1♀, xii. 1911 (all *Dr. S. A. Neave*) ; Undali, 1♂, x. 1926 ; Ebinamba, 1♀, x. 1926 ; Fort Portal, 1♀, xi. 1921 ; Buhundu, 2♂♂ 1♀, on *Markhamia platycalyx*, iii. 1932 ; Bukumbi, 3♀♀, attacking coffee, iii. 1932 ; Kijura, Toro, 1♀, vii. 1935 (all *H. Hargreaves*).

Markhamia is a tree that is widely cultivated to provide poles for hut-building, and the timber is much used by native carpenters.

This species belongs to the group of *S. constrictus*, Fst. Hustache (Rev. Zool. Bot. Afr. **30**, 1937, p. 199) has given a key to some of his own species in this group, but has omitted *uviranus*, Hust., and *overlaeti*, Hust., of which I have cotypes ; and *quadrispinosus*, Qued., and *calcaratus*, Mshl., also belong to it. Unfortunately this key is unreliable, because the sharp sublateral tooth on the hind margin of the prosternum is treated as a definite specific character ; actually in the species known to me in which it occurs it is confined to the female, being absent or only feebly indicated in the male. Moreover, the key states that this tooth is absent in *variabilis*, Hust., and *collarti* var. *ignoratum*, Hust., whereas in female cotypes of these two forms that are before me it is well developed ; it does not, however, occur in females of *overlaeti* and *calcaratus*. Further, I can find no valid characters to separate *collarti* var. *ignoratum* and *falsus*, Hust. (cotypes seen) from *constrictus*, Fst., and must regard them as synonyms.

The present species is most nearly allied to *constrictus*, but does not exhibit the definite symmetrical pale spots on the elytra characteristic of the latter, which differs also in having the eyes much less convex, so that they do not project laterally beyond the temples ; its forehead it much narrower, being only as wide as the dorsal area of the rostrum ; and the prothorax is trapezoidal, with a strong granular sub-basal process on each side projecting obliquely backwards.

Myllocerus spinicollis, sp. n.

♂♀. Derm piceous, with dense uniform pale green scaling above and below, except for an indefinite broad median stripe on the prothorax in which the round scales are rather smaller and more or less greyish, and a broad median area on the two basal ventrites clothed with narrow grey scales.

Head with the eyes lateral, broadly ovate and moderately convex, the forehead much broader than the space between the scrobes. *Rostrum* about as long as the head, transverse (3 : 4), slightly narrowing from the base to the antennae and becoming nearly as wide at the apex as at the base, the apical emargination shallow, the base of the epistome forming a wide obtuse angle ; dorsum shallowly depressed anteriorly, with a very fine low median carina (sometimes almost hidden by scaling), the lateral carinae obtuse but distinct. *Antennae* red-brown ; scape curved, gradually clavate, with subrecumbent pale setae ; funicle with joint 1 longer than 2, 3 and 4 equal.

Prothorax transverse (9 : 14), parallel-sided for a short distance at the apex, then gradually widening to near the base where there is a stout sharp spine directed obliquely backwards, behind which is a strong basal constriction, the base deeply bisinuate and not wider than the apex, which is vertically truncate laterally ; dorsum with a shallow transverse impression at the base and another on each side at one-third from the apex, the punctures hidden by scaling, the setae very short, sparse and suberect. *Elytra* with the sides feebly sinuate behind the roundly rectangular shoulders, widest far behind the middle, separately rounded at the base ; the shallow striae with fine close punctures showing through the scaling, the intervals with a row of very short, curved, spatulate, suberect setae. *Legs* reddish yellowish, with grey scaling, the femora with a minute tooth.

Length 2·8–3·6 mm., breadth 1·4–1·8 mm.

PUNJAB : Rawalpindi, 9♂♂ 9♀♀, attacking " ber " (*Zizyphus jujuba*), vii. 1938.

Closely allied to *M. laetivirens*, Mshl., but readily distinguished from this and the other known Indian species by the sharp lateral spines on the prothorax.

Hyperstylus lineatus, sp. n.

♂♀. Derm black, with dense pale green scaling and dark stripes clothed with dark brown scales ; head with a broad dark median stripe ; prothorax with three broad dark stripes, the middle one the widest, the lateral ones sometimes almost interrupted in the middle and not reaching the base ; elytra with the following intervals dark : 1 (except at apex), 3, 5 (except at apex and base) and 9 ; underside uniformly pale green.

Head with the eyes lateral, broadly oval and moderately convex, the forehead much broader than the space between the scrobes. *Rostrum* as long as the head, transverse (3 : 4), narrowing from the base to the antennae and nearly as wide at the genae as at the base, the hind margin of the epistome forming a wide obtuse angle ; dorsum shallowly impressed in the middle, with only a trace of a fine low carina, the lateral carinae obsolete. *Antennae* rather slender, honey-brown, with the club darker ; scape curved, clavate, with very short sparse appressed setae ; funicle with joint 1 longer than 2, 3 a little longer than 4. *Prothorax* transverse (4 : 5), parallel-sided for a short distance at base and apex and there of equal width, gently rounded laterally in the middle, truncate at base and apex, the apical margin oblique laterally ; dorsum somewhat lower at the base than at the apex, with a feeble impression on each side before and behind the middle, the punctures hidden by dense scaling, the inconspicuous short setae appressed. *Elytra* parallel-sided from the roundly rectangular shoulders to beyond the middle in ♂, slightly widened behind the middle in ♀, truncate at the base, jointly rounded at the apex ; the shallow striae with fine close punctures showing through the scaling, the very short scale-like setae appressed. *Legs* reddish, the femora darker, with fairly dense green scaling.

Length 2·5–2·6 mm., breadth 1·0–1·1 mm.

PUNJAB : Koti, Kuptu, 2♂♂ 1♀, attacking leaves of apple trees, vi. 1938.

Readily recognised from its congeners by its striped markings.

NOTES ON THE BEHAVIOUR OF *GLOSSINA PALLIDIPES* AND *G. BREVIPALPIS*, AND SOME COMPARISONS WITH *G. MORSITANS*.

By Rupert W. Jack,
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The serious situation created by continued incursions on the part of *Glossina pallidipes* and *G. brevipalpis* from Moçambique Territory into the farming area of the southern Melsetter district in S. Rhodesia has necessitated increased attention to these species.

Notes of interest on behaviour in the field, more especially of *pallidipes*, have recently been obtained, owing to the courtesy of His Excellency the Governor of the Moçambique Co's Territory, who has granted ready permission to S. Rhodesian entomologists to carry out investigations on the Portuguese side of the border.

The most accessible densely infested locality has been the tract of country through which runs a motor road from Mt. Selinda in S. Rhodesia, past Spungabera, the seat of Administration of the Mossurize District of the Moçambique Co's Territory, to the Gogoio Mission some twenty miles over the border. This road crosses the Busi River about seven miles from the border, and here there is an excellent pontoon, with natives in attendance to ferry motor vehicles over the river. Both of the species of *Glossina* referred to occur between the border and the river, but are more abundant on the farther side of the latter. A few *morsitans* also occur. The experiments and observations which have supplied the material for the present paper have been made mostly in the vicinity of the road within a few miles of the ferry, from June to September, 1939.

Attraction to Man.

It is well known that neither *pallidipes* nor *brevipalpis* is attracted to man in the same degree as are *morsitans* and some other species of *Glossina.*

The buzzing pestering attack, familiar to workers in dense infestations of *morsitans*, and the settling of the flies in numbers on the backs of one's natives and oneself are apparently never experienced in the case of either *pallidipes* or *brevipalpis.* The attack of the last two species on man is quiet and unobtrusive. In the case of *pallidipes*, it appears rarely to take place above the knee, at least on walking man (see also Harris 1930, p. 33). In very long grass the writer was, however, once attacked by this species on the arm. *G. brevipalpis*, on the other hand, will attack man anywhere, and not uncommonly on the head. When they attack man both species fill themselves readily with blood.

On pp. 144–145 of my paper on *morsitans* (Jack, 1939) the fat contents of 38 male and 19 female *pallidipes* caught on man are given, the mean fat content in both sexes being very low. The numbers have now been increased to 75 males and 49 females with no material change, the mean fat content of each sex being :—males, 0·57 mgm. ; females, 0·35 mgm. The figures will be examined more closely later (see Tables V, VI and VII). *G. pallidipes*, male or female, therefore only attacks man when very hungry.

It should be mentioned that the total number of female *pallidipes* caught on man and analysed was 48, but one female was quite unique in this series, and has been excluded. She contained 8·4 mgm. of fat with a dry weight (less fat) of 14·4 mgm. (see Table VI), and is thought to have settled on man more or less accidentally.

She contained a small larva. The total catch of *pallidipes* on man in 1939 was 70 flies (39 males, 31 females), the proportion of females being thus 44 per cent.

G. brevipalpis seems to be less attracted to man even than *pallidipes*, and no considerable figures are available concerning the fat content of individuals of this species caught in this way. The few flies of this species caught on man which have been analysed have mostly been very low in fat content in the case of both sexes, but here again we have an extraordinary fly (female) which apparently engorged itself at or shortly previous to the time of capture. The abdomen was full of blood and the dry weight (including the fat) was 85·0 mgm., the fat content being 17·9 mgm. There is no doubt about these figures. The fly was given a second period in the oven after the first weighing, and showed no reduction in weight. It contained a small larva.

Attraction to Animals.

A donkey was used for the purpose of obtaining specimens of both species of tsetse attracted to the nearest substitute for a natural host. Collections were made mostly along the road.

The total catch of *pallidipes* on the donkey was 710 flies (396 males ; 314 females), the proportion of females being thus 44 per cent. One hundred and fifty (150) males and 250 females were analysed individually for fat, the mean fat contents being :—Males, 1·21 mgm. ; females, 1·68 mgm. Detailed figures are given later (Tables V, VI and VII). The mean fat content is relatively low in both sexes, indicating that, in general, neither sex of this species is attracted to a host except when hungry.

The catch of *brevipalpis* was much smaller, only 86 flies (72 males and 14 females) being caught, giving a female proportion of 16 per cent. Sixty-four (64) males and 13 females were analysed and the results are shown in the following tables.

TABLE I.

Analysis for Fat of Male and Female G. brevipalpis *caught on a Donkey, August* 1939.

Sex	No. of flies	Mean dry weight	Mean dry weight less fat	Mean weight of fat	Fat as per cent of dry weight
		Mgm.	Mgm.	Mgm.	Mean
Males ...	64	23·2	19·6	3·6 SE 0·4710	12·7
Females ...	13	26·4	23·5	2·9 SE 1·159	7·6

The distribution of individual weights of fat in the above group is shown in the following table :—

TABLE II.

Distribution of the Weights of Fat in 64 *Male and* 13 *Female* G. brevipalpis *caught on a Donkey, August* 1939.

Sex	Milligrams of fat											Total no. of flies
	Under 1·0	1·0–1·9	2·0–2·9	3·0–3·9	4·0–4·9	5·0–5·9	6·0–6·9	7·0–7·9	8·0–8·9	9·0–9·9	10+	
Males ...	27	4	3	6	5	3	3	4	3	1	7	64
Females	8	1	—	1	—	—	1	—	—	—	2	13

The maximum weight of fat in the males was 13·8 mgm. and in the females 11·8 mgm. Of the four females containing over 3 mgm. of fat one was not pregnant, two contained small larvae, and one contained a late 2nd stage larva.

The indications are that, as with *morsitans*, the males of *brevipalpis* are attracted to a host whether hungry or otherwise, but the females probably only when ready to feed.

Attraction to Motor Vehicles.

Further experience leads to the conclusion that, whilst both *pallidipes* and *brevipalpis* are sometimes attracted to moving motor vehicles, their reaction to this attractant is very weak compared with that of *morsitans*.

Along a road on which *pallidipes* were collected in hundreds on a donkey and on screens, and near which, during the same period, 2,430 *pallidipes* were caught in traps, the total number of flies of this species taken on a motor vehicle, making at least two journeys each way per diem, was 19 (12 males, 7 females). It should be stated that a continuous watch was kept by all the party for tsetse-flies attracted to the vehicle during journeys, as such flies were desired for analysis.

Analysis of such small numbers has little value. The *pallidipes* analysed returned mean fat contents of :—10 males, 1·1 mgm ; 6 females, 1·1 mgm. The *brevipalpis* returned mean fat contents of :—10 males, 2·2 mgm. ; 5 females, 0·7 mgm. The fat contents of all the females were small in both species, not exceeding 1·7 mgm. (*pallidipes*). One *pallidipes* male contained 5·0 mgm. (33 per cent. of dry weight), and three *brevipalpis* males, 8·0 mgm. (30 per cent. dry weight), 4·5 mgm. (18 per cent. dry weight) and 3·7 mgm. (14 per cent. dry weight) of fat respectively. It would seem that the males of both species may be attracted occasionally to motor vehicles when in fat condition, but it is uncertain whether fat females are attracted.

Attraction to a Moving Screen.

The only screen used for collecting *pallidipes* and *brevipalpis* was a dark grey blanket doubled so as to measure about 5 ft. × 3 ft. and carried on a pole between two natives. A second pole was inserted into the fold at the lower edge and kept the blanket extended.

The screen was carried along the road at a very slow pace by two natives, with a catcher in attendance, and was found to attract *pallidipes* fairly well, and *brevipalpis* less freely. On two days in June, for instance, 53 *pallidipes* (24 males, 29 females) were caught on the screen and 14 *brevipalpis* (11 males and 3 females). In September occasional collections yielded 54 *pallidipes* (32 males, 22 females), and only 2 *brevipalpis* (1 male, 1 female).

Twenty-four (24) male and 29 female *pallidipes* caught on the screen in June were analysed. The males returned a mean fat content of 0·56 mgm. (SE 0·0904), and the females a mean of 1·75 mgm. (SE 0·3465). The 11 male *brevipalpis* caught on the screen in September returned a mean fat content of 0·88 mgm. (SE 0·3540) and the 3 females a mean of 0·97 mgm. (SE 0·2027). The catches of *pallidipes* in September gave the results :—28 males, mean fat 1·21 mgm. (SE 0·1936) ; 22 females, mean fat 1·48 mgm. (SE 0·4116). The returns of fat from the *pallidipes* males caught on the screen are low compared with those in the catches on the donkey, but the females caught on screen and donkey respectively were in a similar condition of nourishment. The available figures are analysed further in Tables V, VI and VII.

There was a conspicuous difference between *pallidipes* and *brevipalpis* in respect of the position of alighting on the screen. *G. pallidipes* almost invariably alighted on the bottom bar, and frequently directly underneath ; *brevipalpis* alighted anywhere on the sides of the screen and not infrequently on the top bar. This was also observed when using the screens at another time in another locality.

Attraction to Traps.

Several different forms of traps were tested during August and September, including (1) the exact Harris model (hessian), (2) our No. VIII octagonal model (Jack, 1939, fig. 26) with a body of black sateen, (3) certain other models very similar to the Harris, with either hessian or black cloth, (4) a small modified Harris trap with black cloth, which was christened the " Tin-top " and will be described in more detail later, (5) some " crinoline " forms and (6) Swynnerton's A.S. Trap, the screen of which was, however, probably not correct.

Although the tests were made in the normally dry months of August and September, the weather was unusually humid and several showers of rain occurred. On two sunny days at 1 p.m. the relative humidities, taken with a whirling hygrometer, were 63 per cent. and 64 per cent. respectively, and heavy dews occurred at night. The weather was thus not very favourable for trapping.

The largest catches were made by the No. VIII model (black), whilst the exact Harris and very similar models caught fairly well, as also did the " Tin Top." The " crinoline " type caught a few flies only, whilst the A.S. traps caught practically nothing, probably owing to an incorrect screen being used. In all, 2,375 out of 2,436 *pallidipes* caught in the traps were taken by the No. VIII, the Harris (and similar models) and the " Tin Top," all of which are more or less similar in construction, although the bodies of some were of hessian and others of black sateen.

These particulars are not intended to indicate the relative efficiency of the different types of traps. They are necessary because all the trapped flies were mixed together and could not be separated for analysis. The flies were collected from the traps each morning and, in view of the fact that many flies would have been exposed to the sun the previous day, some loss of weight and expenditure of fat presumably occurred. A fly spray was used for killing the flies, and in order to remove any essential oil which might have been adherent to the flies, the latter were rinsed for one minute in petroleum ether.

One hundred (100) males and 200 females were analysed individually. Four hundred (400) males and 400 females were analysed in lots of 100 each in a Soxhlett extraction apparatus, and, of these, 100 males and 100 females were dried and weighed individually after extraction of their fat. The mean fat content of 500 trapped males was 1·23 mgm., and the mean fat content of 600 trapped females was 4·48 mgm.

It will be seen, therefore, that, whilst the mean fat content of the trapped males did not differ materially from that of the males caught on a donkey, the trapped females were on an average very much fatter than the females caught on the animal. The proportion of female *pallidipes* caught in the traps was 61·26 per cent. Further analysis of the available figures is given in Tables V, VI and VII.

The traps caught only 39 *brevipalpis* (19 males, 20 females) during this period as against 2,430 *pallidipes*. Of these 39 flies, 35 were caught in black traps, and 33 of the 35 were caught by the No. VIII model. Only 6 male and 8 female *brevipalpis* caught in the traps have been analysed. The fat in the males varied from 0·7 mgm. to 3·9 mgm., and in the females from 0·8 mgm. to 15·9 mgm. It would seem that females in all stages of nourishment may enter the traps, as in the case of other species, but whether only hungry males are caught is uncertain ; 3·9 mgm. of fat is relatively low for a large species like *brevipalpis*, being in this instance only 10·7 per cent. of the fly's dry weight (see Table V).

No precise figures were obtained concerning the time of day when the traps caught most flies, but Mr. W. L. Williams, who was in immediate charge of the traps, states in his report :—" *G. pallidipes*' time of greatest activity is usually in the late afternoon, the actual time varying with the temperature and the brightness of the day. The time when most flies enter the traps is usually between 4 p.m. and 5.30 p.m." This agrees generally with Swynnerton's statement (1936, p. 107). Experience during these tests indicated that the traps functioned best when placed in such a position that they received the rays of the sun in the late afternoon, this deduction being also due to Mr. Williams.

On pp. 169–170 of the recent paper on *morsitans* (Jack, 1939, p. 169), it is stated that attempts to catch *Stomoxys* in traps of the Harris and similar patterns in S. Rhodesia had failed almost completely. The experiments in this connection were carried out by Mr. A. Cuthbertson of the writer's staff. Mr. Cuthbertson states that the species of *Stomoxys* mainly concerned were *calcitrans*, L., *nigra*, Macq., and *bilineata*, Grünb., the two former species being dominant. It is of interest that, at the scene of the experiments under review, *Stomoxys* was caught in large numbers particularly in the black No. VIII model. The flies caught in this instance were over 90 per cent. *omega*, Newst., with some *brunnipes*, Grünb.

Many Tabanids were also caught in the traps and again the black No. VIII model caught the largest numbers. The species mainly concerned to date have been *Tabanus gratus*, Lw., *T. insignis*, Lw., *T. denshamii*, Aust., *T. atrimanus*, Lw., *T. diversus*, Ric., *T. obliquemaculata*, Macq., *Pangonius pallidipennis*, Ric., and *Phara obscura*, Ric. All the Tabanids caught in the traps were females.

G. brevipalpis on Roads and Footpaths.

The habit of *brevipalpis* males of settling on roads and footpaths in the late evening is well known. Collections of such flies were made, and in all 131 were caught, of which 130 were males. Figures have already been given of the mean weight of fat in 35 male *brevipalpis* caught off the road in the evening, namely 6·46 mgm. (max. 11·0 mgm., min. 2·7 mgm.) (Jack, 1939, p. 145). Analysis of 71 further specimens confirms the fact that these males, with some exceptions, are fat and obviously not hungry.

TABLE III.

Distribution of Weight of Fat in 106 G. brevipalpis *Males caught while resting on a Road in the late Evening.*

Milligrams of fat									Total no. of flies	Mean fat mgm.	Fat as per cent. dry weight, mean
Under 2·0	2·0–3·9	4·0–5·9	6·0–7·9	8·0–9·9	10·0–11·9	12·0–13·9	14·0–15·9	16+			
3	13	28	29	22	9	—	—	2	106	6·8	24·5

The maximum individual weight of fat amongst the above males was 19·3 mgm.

TABLE IV.

Distribution of Dry Weight (less Fat) in 106 G brevipalpis *Males caught while resting on a Road in the late Evening.*

Dry weight less fat in milligrams									Total no. of flies	Mean dry weight (less fat)
Under 14	14·0–15·9	16·0–17·9	18·0–19·9	20·0–21·9	22·0–23·9	24·0–25·9	26·0–27·9	28·+		
3	7	10	21	30	26	7	1	1	106	20·4

The maximum dry weight, less fat, amongst the above flies was 28·0 mgm.

Male *brevipalpis* resting on the road in the evening appear to be indifferent to man, animal, vehicle, screen or trap. The habit appears to be exhibited by other members of the *fusca* group of *Glossina*, e.g. *fusca*, *schwetzi* and *longipennis*, but it is not exhibited by *pallidipes* or *morsitans*.

Differences in Alimentary Condition of G. pallidipes in relation to different Attractants.

The available figures referring to the alimentary condition of *pallidipes* caught in different circumstances are included in the following tables to facilitate comparison.

TABLE V.

Mean Dry Weight and mean Fat Content of pallidipes *caught by means of different Attractants in the Field ; also the Percentage of Females in each Collection.*
Advanced Larvae=3·0 *mm. or more in Length.*

Attractant	No. of flies analysed	Sex	Mean dry weight mgm.	Mean fat mgm.	Fat as per cent. of dry weight means	Percentage of females in catches	Percentage females with advanced larvae
Man ...	75	Males	10·3	0·57 SE 0·0731	4·6	39* (127 flies)	Nil
	49	Females	9·5	0·35 SE 0·0405	3·7		
Donkey ...	150	Males	11·0	1·21	10·4	44 (710 flies)	2·4
	250	Females	12·2	1·68	11·3		
Screen ...	52	Males	10·7	0·94 SE 0·1220	8·3	50 (103 flies)	Nil
	51	Females	11·3	1·66 SE 0·2639	12·5		
Traps ...	500	Males	10·9	1·23	10·1 †	61 (2·430 flies)	14·5
	600	Females	19·4	4·48	22·0 †		

* This includes flies caught in 1937 as well as 1939. The catch on man in 1939 amounted to 39 males and 31 females, *i.e.*, 44 per cent. females, as stated previously.

† From 100 males and 200 females.

With regard to the percentage of females containing advanced larvae, no dissections were made in the case of catches on man, but there is no record to date of a *pallidipes* female with less than 4·0 mgm. of fat, containing an advanced larva as above. Forty-five (45) out of the 47 females caught on man contained less than 1 mgm. of fat, the remaining two containing 1·8 and 1·3 mgm. respectively.

In the case of the females caught on the donkey and on the screen, all showing over 2·0 mgm. of fat were dissected, as well as many others. Twenty-two females in one batch off the screen were all dissected. All the 600 trapped females were dissected.

It may be stated here that in Tables XIV, XV and XLIX of my paper on *morsitans* (Jack, 1939) and also in Tables III, IV and V of the Appendix, many small second stage larvae were probably classified as first stage, seeing that, according to Roubaud (1909), the first stage occupies only a few hours. This point was overlooked at the

TABLE VI.

Distribution of the Weights of Fat in pallidipes *Adults caught by means of different Attractants in the Field.*

Attractant	Sex of flies	Milligrams of fat											Total flies	Mean fat mgm.
		Under1·0	1·0–1·9	2·0–2·9	3·0–3·9	4·0–4·9	5·0–5·9	6·0–6·9	7·0–7·9	8·0–8·9	9·0–9·9	10+		
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		
Man ...	M	85·0	9·6	4·1	1·4	—	—	—	—	—	—	—	75	0·57
	F	95·8	4·3	—	—	—	—	—	—	—	—	—	49	0·35
Donkey ...	M	49·3	31·3	13·3	1·3	4·0	1·0	—	—	—	—	—	150	1·21
	F	50·0	28·0	7·2	4·0	1·6	1·2	2·4	2·0	2·4	0·4	0·8	250	1·68
Screen ...	M	57·7	26·9	9·6	5·8	—	—	—	—	—	—	—	52	0·94
	F	53·0	19·6	7·8	5·9	—	9·8	3·9	—	—	—	—	51	1·66
Traps ...	M	48·0	40·0	7·0	3·0	2·0	—	—	—	—	—	—	100	1·14
	F	10·5	13·5	11·0	5·5	11·5	11·0	9·0	12·5	7·5	5·5	2·5	200	4·73

TABLE VII.

Distribution of the Dry Weights, less Fat, of pallidipes *Adults caught by means of different Attractants in the Field.*

Attractant	Sex of flies	Dry weight, less fat, in milligrams								Total flies	Mean dry weight less fat mgm.
		Under 8·0	8·0–9·9	10·0–11·9	12·0–13·9	14·0–15·9	16·0–17·9	18·0–19·9	20+		
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		
Man	M	32·0	12·5	36·1	16·7	2·8	—	—	—	72*	9·7
	F	42·5	23·4	14·9	12·8	6·4	—	—	—	49	9·1
Donkey ...	M	28·8	28·8	26·0	14·4	2·6	—	—	—	146*	9·8
	F	29·0	30·7	12·9	9·3	12·9	4·9	2·0	1·2	248*	10·5
Screen ...	M	21·1	26·9	40·3	9·6	—	1·9	—	—	52	9·8
	F	31·4	29·4	19·6	11·8	7·8	—	—	—	51	9·6
Traps	M	25·2	32·3	28·2	13·1	0·5	0·5	0·5	—	199	9·7
	F	6·3	7·8	5·3	19·0	26·0	22·0	10·3	3·7	300	14·4

* From these groups have been excluded certain flies which appear certainly to have taken blood at the time of capture.

time. It appears that a closer study of the development of the larva in the female tsetse might not be unprofitable, particularly in reference to the time of the moult to the third stage, on which the evidence appears to be rather vague. In the tables mentioned it may be taken that any larva classified as second stage measured 2 mm. or more in length and the significance of the tables is not in general affected by the faulty classification.

Table XLIX in the paper referred to has, however, no significance in indicating reluctance of female *morsitans* to attack man for another reason, namely that female tsetse do not normally feed during about three days preceding larviposition, the last feed before larviposition being taken when the larva is still small (see H. Mellanby, 1937, p. 135). The fact that in Table V of the present paper the percentage of female *pallidipes* which contain advanced larvae, caught on a donkey, is no higher than in the female *morsitans* caught on man, will be noted in this connection. The writer was in fact guilty of a regrettable oversight, and a mimeographed statement in this connection has been forwarded to all recipients of copies of the original paper.

It may be deduced from the above, that the capture on a host, including man, of any considerable proportion of females containing an advanced larva, far from being an indication of a thriving tsetse community, betrays an insufficiency of opportunity of feeding in the locality concerned. Female *morsitans* containing third stage larvae, for instance, are sometimes caught feeding on man and animals, and in such cases the prelarviposition meal has certainly been postponed through lack of opportunity.

It is not impossible that certain other of the flies attracted to man and donkey may have taken a little blood before capture, which would, of course, increase the dry weight. Captures on the screen and in the traps would be free from any complications of this nature.

Estimation of the State of Hunger with dry Tsetse-flies.

In the course of study of the behaviour of tsetse-flies, it has been necessary to deal at Salisbury with dry material received from the field, and to estimate the condition of hunger of the flies at death on the basis of what it is possible to ascertain from such dry specimens. The fat content has limitations as an indicator of appetite. Evidence has been produced in the case of *morsitans* that, whilst the weight of fat is in general a measure of the state of nourishment of the fly, it is not a reliable indication of the fly's desire to feed or otherwise. A very low fat content certainly indicates an advanced stage of hunger, except for a relatively short period after a meal, but a considerable weight of fat does not necessarily imply lack of appetite (Jack, 1939, pp. 88-89).

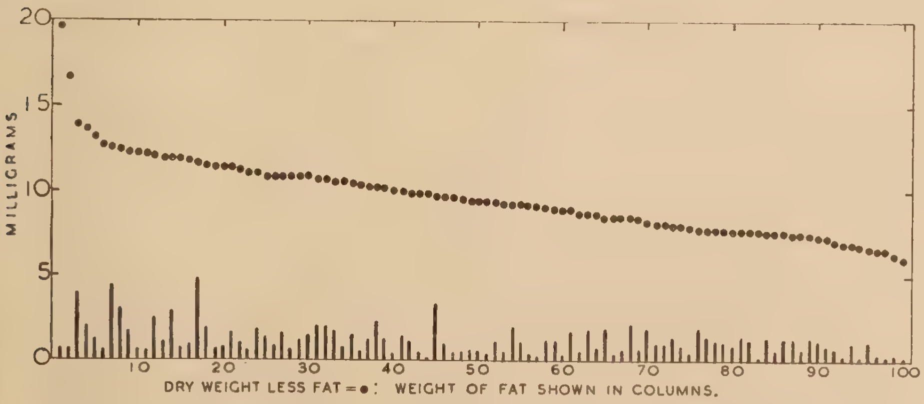
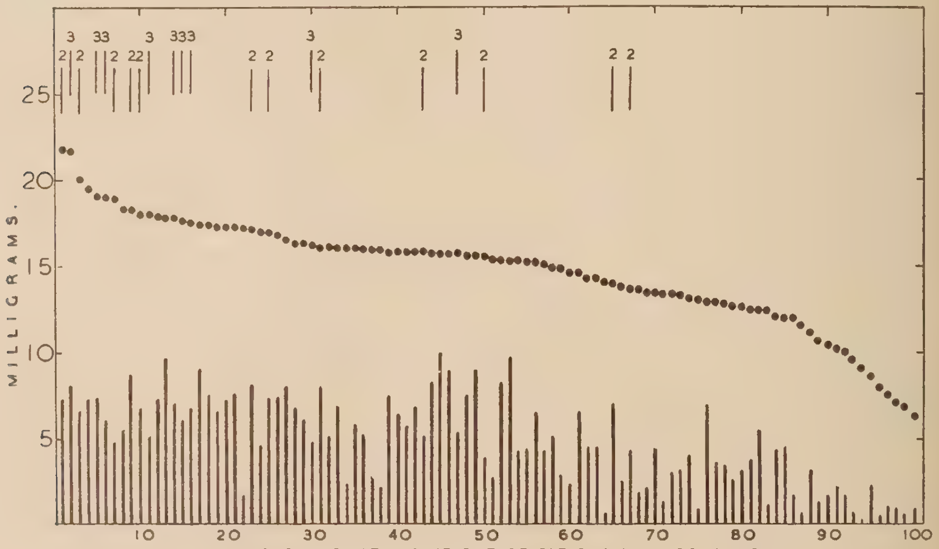


Fig. 1. Showing individually the dry weights, less fat, and the corresponding weights of fat in a random sample of 100 *pallidipes* males caught in traps, Aug.–Sept. 1939.

Having regard to the above, it would appear that a better measure of the alimentary condition of the fly might be the weight of solids other than fat, *i.e.*, the dry weight of the fly after ether extraction.

The diagrams have been prepared to show, *inter alia*, that the weight of non-fatty solids is far from being closely correlated with the weight of fat. The dry weights, less fat, of groups of 100 flies each, caught by means of different attractants, have been plotted in decreasing order, and the fat in each fly has been indicated by a column beneath. This arrangement brings out clearly the lack of close correlation between the weight of non-fatty solids and the fat content in the individual flies, and in general facilitates comparison between the different groups.

The exceptionally heavy flies, which appear in most instances on the extreme left of the diagrams, are flies which had apparently fed at the time of, or very shortly before, capture. The very light flies on the extreme right of the diagrams consist largely of young unfed flies.



DRY WEIGHT LESS FAT= ●: WEIGHT OF FAT SHOWN IN COLUMNS.
2 SIGNIFIES 2ND STAGE LARVA 3 MM OR MORE IN LENGTH: 3 SIGNIFIES 3RD STAGE LARVA
REMAINING FEMALES IN LESS ADVANCED PREGNANCY OR NOT PREGNANT.

Fig. 2. Showing individually the dry weights, less fat, the corresponding weights of fat and the presence, or otherwise, of advanced larvae in a random sample of 100 *pallidipes* females caught in traps, Aug.–Sept. 1939.

There is, of course, a very general correlation between the dry weight, less fat, and the fat content, in that a random sample, including a reasonable number of heavier flies, will in general average higher in fat than a similar sample of lighter flies, but it is clear that many flies which would be classed as hungry by their non-fatty solids would be classed as non-hungry by their fat and *vice versa.*

The lack of correlation between the two measurements is to be expected from what has been said to the effect that the fat content does not determine appetite. To be added to this are (1) the great variation in the weight of blood ingested by different flies, (2) the relatively small addition to the fat content provided by a single meal (Jack, 1939; Append. pp.i-v), and (3) the fact that flies with a rising fat content may be included in the sample.

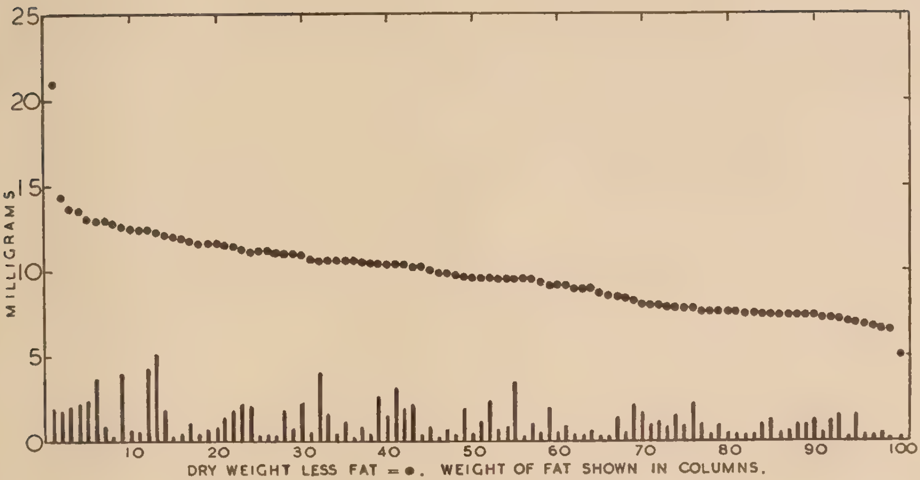


Fig. 3. Showing individually the dry weights, less fat, and the corresponding weights of fat in a random sample of 100 *pallidipes* males caught on a donkey, August 1939.

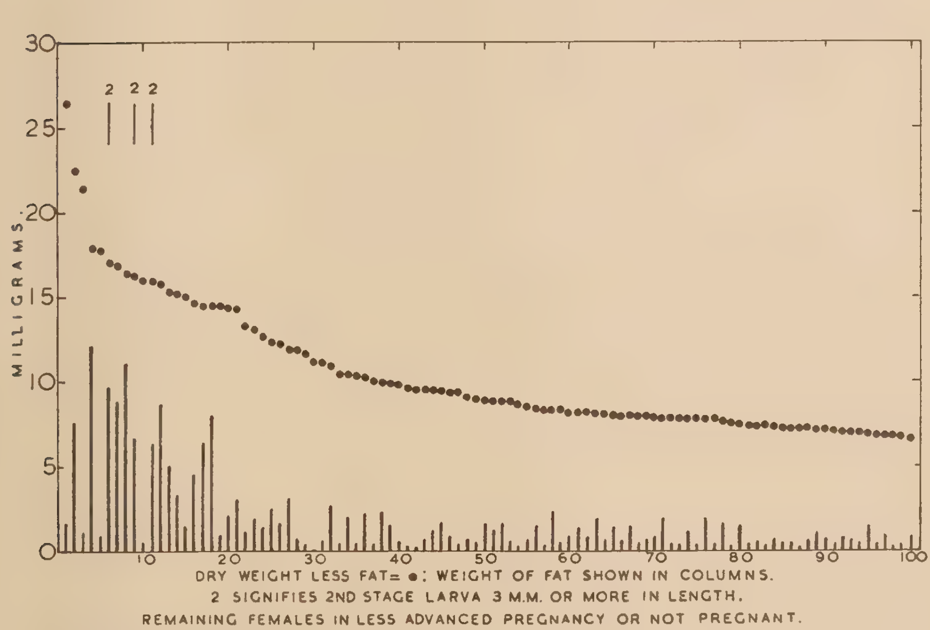


Fig. 4. Showing individually the dry weights, less fat, the corresponding weights of fat, and the presence, or otherwise, of advanced larvae in a random sample of 100 *pallidipes* females caught on a donkey, August 1939.

With regard to the non-fatty solids, it is obvious that, for the purpose of study of behaviour, the possibility of the fly having taken some blood at the time of capture on a living attractant introduces a source of error, which is absent if the fat is used as the measurement.

Another difficulty with the non-fatty solids lies in the very considerable variation in the weight of the flies on emergence. The figures available in the case of *morsitans* show that, even in small samples of ten newly emerged flies of the same sex, the range of variation in the dry weight after ether extraction is quite commonly in the proportion of 2 : 3 (*e.g.* min. 4·0 mgm. ; max. 6·0 mgm.). In larger samples the range may, of course, be greater.

The variation in weight on emergence is obviously the reflection of variation in size which means capacity for ingesting blood. The weight of additional solids necessary to bring a fly to a given alimentary condition will be more of less proportionate to its initial weight. The significance of the dry weight, less fat, lacks precision on this account. For instance, any *morsitans* males with a dry weight, less fat, from say 7 mgm. to 12 mgm. might be in the same alimentary condition.

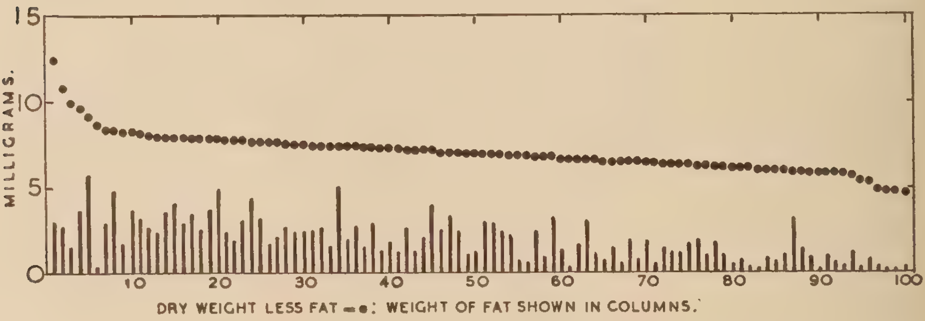


Fig. 5. Showing individually the dry weights, less fat, and the corresponding weights of fat in a random sample of 100 *morsitans* males caught on man, 2–3.iii.38.

Seeing that there is a general tendency for the flies containing more non-fatty solids to contain also more fat (see figs.) it is to be expected that, for the purposes of comparison between considerable samples, the one measure will support the other, and in general this is the case. Referring to Tables V and VII, however, it will be noted that the difference between the mean weights of fat in male *pallidipes* caught on man and donkey respectively is highly significant, but that there is practically no difference between the respective means of the weight of solids other than fat, namely,

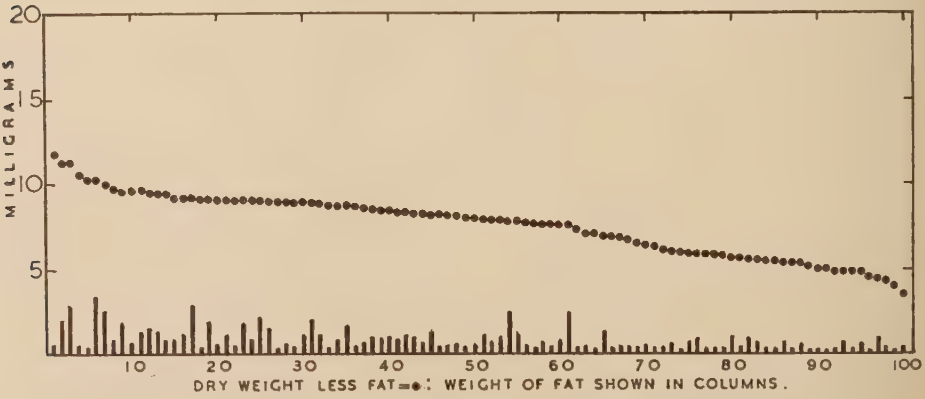


Fig. 6. Showing individually the dry weights, less fat, and the corresponding weights of fat in a random sample of 100 *morsitans* females caught on man, March–April 1938.

9·7 mgm. and 9·8 mgm. In fact, the males caught on all four attractants (Table VIII) show no significant difference in the means of their non-fatty solids, although there are differences in the mean fat contents. The reason for this is probably that, after a certain point, fat is lost proportionately much more rapidly than other solids; in fact non-fatty solids obviously cannot be reduced beyond a certain level.

The fat can, of course, be expressed in percentage of the dry weight. This is a useful measurement in the case of unfed flies and also at times in the case of fed flies. The percentage in the case of unfed flies is, however, not directly comparable with that in fed flies, owing to the greater weight of other solids in the latter case, and this introduces complications.

Over a series the weight of fat dominates the percentage, and the extra work involved in working out the latter is doubtfully justified in the case of considerable groups of fed flies.

It may also be noted that in instances where the fat content is misleading as an indication of hunger, as it is in the case of flies with rising fat contents, the percentage of fat to dry weight is still more misleading.

To sum up, both the weight of fat and the weight of solids other than fat need to be taken into consideration. The first is a direct indication of the state of *nourishment* of the fly after attainment of the maximum weight of fat following a meal. It indicates the quantity of assimilated reserves, although it does not fully measure them. The weight of non-fatty solids is more indicative of the alimentary condition of the fly, as it may include unassimilated solids in the gut and solids in process of assimilation and distribution. The usefulness of the weight of non-fatty solids is limited in the diminishing direction by the fact that it includes the body of the fly and cannot be reduced beyond a certain point. The natural variation in the size of the flies removes all precision from the significance of their weight, and for purposes of comparison considerable samples are needed. The dry weight, less fat, it may be stated, is useful as an indication of youth.

Pregnancy in female tsetses, of course, complicates all measurements in respect of hunger, and dissection is necessary as an aid to interpretation of figures obtained.

Differences in Reaction to various Stimuli between G. morsitans and pallidipes.

We are now in a position to consider the difference in reaction to various stimuli between *morsitans* and *pallidipes*, and also to a less extent *brevipalpis*, as influenced by the physiological and especially alimentary condition of the flies.

The data concerning the influence of physiological condition on the reactions of *morsitans* have been given in the previous paper dealing with that species (Jack, 1939, Part II and Appendix).

A broad provisional interpretation of the available facts can be set out in general terms as in Table VIII.

On the basis of the foregoing, we can explain the general proportion of females in catches by means of most, but not all, of the attractants. In Table IX are included the known facts concerning the proportion of males and females caught by means of different attractants.

It may be remarked that the actual proportion of females in 710 *pallidipes* caught on the donkey was 44 per cent., which is below equality. Harris (1930, Table I), however, records the female proportion in 1,613 *pallidipes* captured on a bait ox as 56 per cent. Conditions presumably affect the proportion of females coming to animals. It appears, therefore, to be justifiable to state that the sexes in this species are, in general, more or less equally attracted to an animal host.

TABLE VIII.

Effect of Alimentary Condition of three Species of Tsetse in their Reactions to different Attractants.

V.H. = very hungry ; H = hungry, *i.e.*, with normal appetite ;
N.H. = non-hungry ; W = attraction weak.

Species	Sex	Condition	Reaction to					
			Man (resting)	Man (moving)	Animal (moving)	Motor vehicle (moving)	Harris type traps	Dark grey screen (moving)
morsitans ...	M	V.H.	+	+	+	+	+	No data
		H.		+	+	+	+	
		N.H.		+	+	+		
	F	V.H.	+	+	+	+	+	
		H.			+	+	+	
		N.H.				(?)	+(?)	
pallidipes ...	M	V.H.	No Data	+	+	+ (w)	+	+
		H.			+	+ (w)	+	+(?)
		N.H.						
	F	V.H.		+	+	+ (w)	+	+
		H.			+	+ (w)	+	+
		N.H.					+	
brevipalpis ...	M	V.H.	No Data	+	+	+ (w)	+ (w)	+ (w)
		H.			+	+ (w)	+ (w)	+ (?)
		N.H.			+	?	?	
	F	V.H.		+	+	+ (w)	+ (w)	+ (w)
		H.			+	?	+ (w)	?
		N.H.					+ (w)	

TABLE IX.

General Proportions of the Sexes in different Species of Glossina *caught by means of different Attractants.*

	Man (resting)	Man (moving)	Animal (moving slowly)	Motor vehicle (moving)	Harris type traps	Dark grey screen (moving slowly)
morsitans ...	M=F (E)	M>F (E)	M>F (E)	M>F	M=F	
pallidipes ...	—	M=F (E)	M=F (E)	(Too few)	M<F (E)	M=F
brevipalpis ...	—	(Too few)	M>F (E)	(Too few)	M=F (Few flies only)	M>F

(E) indicates that the proportion of the sexes is explained by the effect of physiological condition in the different species and sexes, as determined by analysis of attracted flies, on their reaction to the attractants.

The fact that male *morsitans* are caught in excess on a motor vehicle is still very far from being explained by analysis of flies so caught (Jack, 1939, p. 149) and further investigation is needed.

It is also not clear why a marked excess of female *morsitans* is not caught in traps, as is the case with *pallidipes* (see Jack, 1939, Table LVI). Our records of the percentage of female *morsitans* caught in traps include considerable numbers caught directly from ranging flies without the intervention of a motor vehicle, and the proportion of females was not in excess of that of the males (Jack, 1939, p. 158). Unfortunately we have no analyses of *morsitans* caught in this way. The proportion of females caught in traps may be influenced by the state of nourishment of the fly community in the locality concerned, but the question requires further investigation.

It is noteworthy that in Table VIII it has not been possible to indicate any effective attractant for non-hungry *pallidipes* males. Such males in the case of *morsitans* come to moving objects, *e.g.* man, animal and vehicle. In the case of *brevipalpis* they are known to frequent roads and footpaths. The behaviour of non-hungry *pallidipes* males is, however, quite unknown. The normal function of well-nourished tsetse males is presumably to fertilise the females. Haunting a host, as in the case of *morsitans*, should bring such males into contact with females, but the fact that the latter, when attracted to animals, are in general desirous of feeding would appear to militate against a host constituting the best meeting place. The well-nourished *brevipalpis* males seen on roads and footpaths in the evening may be waiting for females, but we have been able to obtain no direct evidence to this effect. Non-hungry *pallidipes* males presumably meet the females generally in and around the forest.

Some of the deductions included in Table VIII are susceptible of further elucidation. Postulating that in the fly community as a whole the females contain on an average rather more fat than the males, as is to be expected and is certainly the case with *morsitans* in confinement (Jack, 1939, Table XIII), certain consistent differences in the proportion of the mean fat in the females to that in the males, when caught on different attractants, should be manifest. For instance :—

(1) An *animal* attracts male *morsitans* whether hungry or otherwise, but only hungry females. Therefore the mean fat in the males should exceed that in the females. Our figures referring to female *morsitans* caught on an animal are unfortunately rather small, but in Table L of the paper on *morsitans* (Jack, 1939), we have the record of 85 males and 18 females, the mean weight of fat in the females being 50·5 per cent. of that in the males.

(2) An *animal* attracts only hungry *pallidipes* of either sex, and the fat in the females should therefore be rather greater than that in the males. In Table V the mean weight of fat in the females is 131 per cent. of that in the males.

(3) An *animal* attracts *brevipalpis* males whether hungry or otherwise, but only hungry females. The mean fat in the males should, therefore, be greater than that in the females. In Table I, above, the mean female fat is 80 per cent. of the mean male fat. This is a high figure compared with *morsitans* as above, but the time and locality were widely different.

(4) *Man* attracts *morsitans* males whether hungry or otherwise, but only very hungry females. The mean male fat should, therefore, exceed the mean female fat in a still greater degree than in catches on an animal. In catches of *morsitans* on man, at the same time and in the same locality as the catches on a donkey given above (1), the mean female fat was 34·5 per cent. of the male fat (121 males and 21 females), as compared with the 50·5 per cent. fat in *morsitans* caught on the donkey.

The ratio between the male and female fat in *morsitans* caught on man varies greatly with the season, but amongst the extensive records obtained there is no instance, where any considerable groups are concerned, of the mean weight of fat in the females caught on man (or animal) equalling that of the males caught during the same period.

(5) *Man* attracts *pallidipes* of either sex only when very hungry. The mean fat content in both sexes should, therefore, be very low and approximately equal (see Table V above).

(6) *Traps* catch only decidedly hungry male *morsitans*, but females in all stages of nourishment and pregnancy, at least out of a selection presented by a motor vehicle. The fatter females, however, enter the traps more freely on the whole than the leaner females (Jack, 1939, Table LVII). The mean female fat in trapped *morsitans* should, therefore, greatly exceed that of the males. In Table LVI of the paper on *morsitans* (*l.c.*) the mean female fat is 239 per cent. of that of the males (40 males, 39 females).

(7) *Traps* catch only decidedly hungry male *pallidipes* but females in all stages of nourishment, with a preference for the fatter females (see below). The mean female fat should, therefore, greatly exceed that of the males. In Table V the mean female fat in the 600 trapped females is 365 per cent. of that in the 500 trapped males. In connection with the comparison with *morsitans* above, the difference in the circumstances of the catches is to be borne in mind. The fattest female *morsitans* are apparently not attracted to a motor vehicle.

The catching of tsetse-flies by the types of traps with which we are dealing involves two processes, namely : (1) attraction to the exterior of the trap and (2) attraction to the interior of the trap. It is by no means certain that (1) necessarily involves (2).

Referring to the catches of *morsitans* made at the same time (1) on a black screen and (2) in a Harris trap covered with black cloth (Jack, 1939, p. 161), in both cases using flies run up by means of a lorry, it has already been noted that the selection of flies attracted to the black screen is not altogether the same physiologically as that caught in the black trap. Moreover, the physiological condition of the flies caught on the sunny side of the screen is not the same as that of the flies caught on the shady side, at least in the case of the females (*l.c.* Table LVI).

In the case of the males, the screen as a whole attracted the leaner individuals (mean fat, 1·42 mgm.) from those brought up by the lorry (mean fat, 1·70 mgm.), whilst the trap caught still leaner individuals (mean fat, 0·98 mgm.).

In the case of the females, the sunny side of the screen attracted the leaner individuals (mean fat 1·09 mgm.) from those brought up by the lorry (mean fat 1·74 mgm.), but the shady side attracted the fatter individuals (mean fat 2·36 mgm.).

The selection of flies attracted to the outside of the black traps would presumably be similar to that attracted to the black screen, and there is a definite indication here that many of the fatter males and of the leaner females attracted to the outside of the trap failed to enter, whilst the leaner males and fatter females entered more freely.

The dry weights, less fat, show that very few young unfed females (under 6 mgm.) either entered the trap or were attracted to the shady side of the screen, whilst young males were well represented in both cases. Flies which have fed only once or twice tend to be light in non-fatty solids, and such females are also poorly represented in the catches.

Table X gives the distribution of the dry weights, less fat, in flies (*morsitans*) caught on different attractants in the course of these experiments.

The reluctance of young females to enter traps appears also to be reflected in the figures obtained with *pallidipes* (Table VII). Females of this species with a dry weight, less fat, of under 8 mgm. are mostly unfed and it will be noted that only

TABLE X.

Distribution in Dry Weight, less Fat, of G. morsitans *caught in the same Locality, and within three Days, by means of different Attractants. The Captures on the Screen and in the Traps were made from Flies run up to the Vicinity by a Motor Lorry (see Jack,* 1938, *Table LVI)*

Attractant	Sex	Dry weight, less fat, in milligrams								Total No. of flies	Mean Dry weight less fat mgm.
		Under 6·0	6·0–6·9	7·0–7·9	8·0–8·9	9·0–9·9	10·0–10·9	11·0–11·9	12·0+		
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		
Lorry	M	25·0	35·0	40·0	—	—	—	—	—	40	6·5 SE 0·1427
	F	15·0	12·5	10·0	15·0	30·0	5·0	7·5	5·0	40	8·3 SE 0·3277
Black screen (sunny side)	M	10·0	65·0	25·0	—	—	—	—	—	20	6·6 SE 0·1268
	F	41·2	—	—	29·4	17·6	—	5·9	5·9	17	7·6 SE 0·6492
Black screen (shady side)	M	50·0	25·0	25·0	—	—	—	—	—	20	5·9 SE 0·2786
	F	5·0	15·0	5·0	15·0	20·0	30·0	10·0	—	20	9·0 SE 0·4339
Trap (Harris with black cloth)	M	30·0	37·5	32·5	—	—	—	—	—	40	6·4 SE 0·1677
	F	2·6	2·6	2·6	10·4	35·9	30·8	15·4	—	39	9·7 SE 0·2094
Man	M	15·0	50·0	35·0	—	—	—	—	—	20	6·6 SE 0·1451
	F	42·0	21·0	10·5	15·8	5·4	5·4	—	—	19	6·7 SE 0·3807

6·3 per cent., out of 300 trapped females weighed, fell into this category. Seeing that the experiments were carried out in August and September, that is, at the time of the spring rise of temperature when a considerable emergence of young flies usually takes place, it is apparent that unfed flies are very much under-represented in the catches whilst the older heavier flies are over-represented.

It may be remarked that, whereas in the trap catches of *pallidipes* females 65 per cent. contained 3·0 mgm. or more of fat, in the case of *morsitans*, 54 per cent. contained under 2 mgm. of fat. The latter percentage might, of course, have been lowered had the trap had an opportunity of catching completely non-hungry females directly from the fly community, but it is none the less evident that female *morsitans* with a low fat content entered the trap relatively freely, the great majority being old flies as above.

The *morsitans* females were caught at a low altitude during the hotter part of the dry season, whilst the trapping of *pallidipes* took place under relatively humid conditions. Seeing that we have evidence that water loss is a potent factor in rendering tsetse-flies more sensitive to heat and light (Jack, 1939, *l.c.*) the explanation of the fact that lean *morsitans* females entered the traps more freely than lean *pallidipes* females, may lie simply in the fact that a low fat content is commonly associated with a low water content in hot dry weather, but not necessarily in humid weather.

An explanation of the figures obtained with trapped *morsitans* has already been attempted (Jack, 1939, p. 170). The figures obtained with *pallidipes* appear to furnish no reason for changing the general import of the views expressed.

There is apparently a considerable variation in degree of impulse towards shade in tsetse-flies. In a certain physiological condition, the fly may be satisfied at once with interruption of the sun's rays, as on the shady side of a screen, whilst in a more advanced condition it may be impelled into still more shady surroundings, as in a trap. It is presumed to be a matter of sensitiveness to light.

In any case, the deduction is that young unfed females on the one hand and well nourished males on the other are little attracted into a black trap, although they may be attracted to its exterior or to a black screen.

There is evidence that young females are more active than young males (Mellanby, K., p. 627, and Jack, 1939, p. 131), which suggests that their tendency to range is greater than that of the males. They are also, presumable, the most sexually active individuals of their sex, at least after a meal. The well-nourished non-hungry males are almost certainly in the most sexually active condition. This mutual characteristic may conceivably be a factor in the reluctance of the fat males and young females to seclude themselves, their dominant impulse being to range around as much as possible. Further light may be thrown on the question when it is possible to ascertain the water ratio in trapped flies. It would also be of interest to obtain analyses of trapped flies at different seasons of the year.

The results of analysis of the trapped *pallidipes* tend to confirm the deduction in the previous paper (Jack, 1939, pp. 167–174), that the attraction to the traps is not a direct hunger reaction. Very hungry females are poorly represented in the catches, whilst definitely non-hungry females are well represented. Whilst, from their fat content and weight, the males of both *morsitans* and *pallidipes* might have been attracted to the traps through hunger, it is hardly conceivable that this factor would influence the reaction of the different sexes in a precisely opposite manner.

A positive reaction to these traps appears, however, to be definitely associated with blood-sucking habits in flies. In the case of *Glossina* and *Stomoxys*, both sexes of which suck blood, both sexes are caught in traps, whilst in the case of Tabanids, of which only the females suck blood, only females have been caught. The last statement refers, in addition to species already mentioned, to 468 *Dorcalaemus* *silverlocki*, Aust., caught in a Harris trap in the Hartley district in 1932. It may be noted that Neave (1912, p. 281) found that female Tabanids, but not males, were attracted to a tent and expressed the view that it was probably the shade which constituted the attraction.

There is some evidence suggesting that blood-sucking insects in general may possibly be more susceptible to heat than related vegetable feeders. According to the writer's tests, the lethal temperature over a three hour period for *Glossina* is 40°C., for *Stomoxys* 42°C., for *Musca* 44°C. (Jack, 1939, p. 5) ; in other words, the degree of completeness of the blood-sucking habit is correlated in these instances, inversely with the resistance to high temperature. Some tests made at Salisbury with *Cimex* indicated a lethal high temperature, over the three hours period, of 40°C., as with *Glossina*. Uvarov quotes Cunningham as giving the very low figures of 30·5–31·5°C. as lethal to fleas in 45 minutes (Uvarov, 1931, Table VI). Further experiments of this nature are obviously needed, especially with the different sexes of Tabanids.

No attempt can be made at this stage to suggest why blood-sucking flies should be more susceptible to heat than other flies, but if this is the case generally, the particular attractiveness to blood-sucking flies of the type of traps with which we are dealing would seem to be explained.

The failure of the traps to catch well nourished male *pallidipes* and the apparent weak attraction for young females, which may be extended to hungry females generally under humid conditions, greatly reduces their value in reference to creation of a barrier of traps across valleys or other avenues of movement of this species. It would appear that a considerable proportion of the flies of both sexes would be liable to pass through such a barrier without being caught.

Incidentally, the fact that well-nourished non-hungry and heavily pregnant females are caught in numbers in traps erected in the open shows that these females range more or less freely through the forest glades, and this is a useful point. There is a temptation to assume that such females are altogether inactive.

A Cheap Trap for G. pallidipes.

It has been judged that there is an opening for the use of tsetse-fly traps for the purpose of determining the most important channels of entry of *pallidipes* from Portuguese territory into the Colony, and also the channels of spread of this species after entry. Moreover, if entry occurs mainly through narrow valleys, as appears to be probable, a barrier of traps might prove useful in conjunction with the border clearing at these points. Furthermore, if any farms were found to have sustained a serious invasion, a concentration of traps might be useful for the purpose of reducing the numbers of the flies.

The Union Government very kindly forwarded a specimen of the latest model of the Harris trap, and quotations were obtained for the construction of these traps in quantity at Salisbury. It was clear from these quotations that, if a large number of these traps were to be ordered, the total expenditure would be very considerable.

The Harris trap catches *pallidipes* excellently under suitable conditions, and it is doubtful if it can be greatly improved upon in this respect. The traps are, however, relatively heavy and cumbersome, making them costly to transport and awkward to carry. It is to be realised that the localities in which the traps are to be used in S. Rhodesia are from 120–150 miles from the railway, and that the country over which the traps have eventually to be distributed is very broken in many parts. Finally, the cost is a highly important matter in a colony with limited resources.

Experiments in reducing the weight, size and cost of the traps were accordingly undertaken. In these tests a considerable variety of traps were included as stated on p. 410. Of the cheaper models, the trap which gave the best results was that christened the "Tin Top" on account of the catching cage being constructed of galvanised iron instead of wood, as in most of the other models, including the Harris trap. The simple details of its construction are shown in the following diagram.

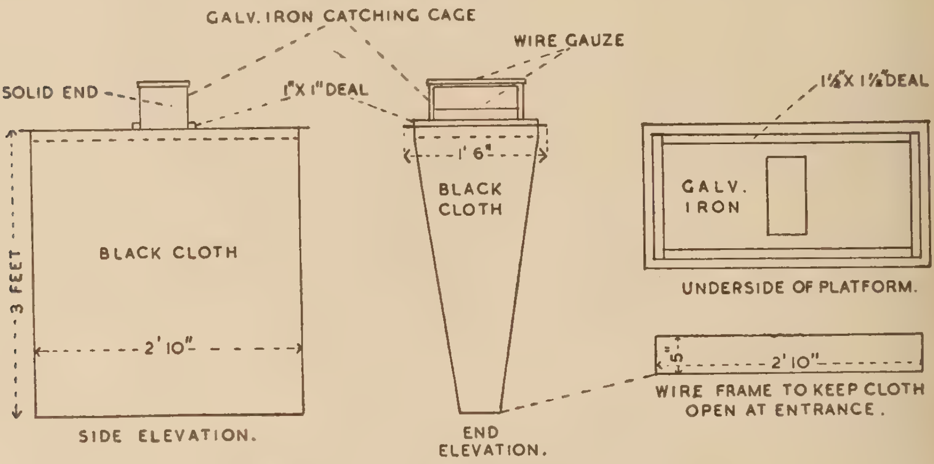


Fig. 7. Details of construction of a cheaper modification of the Harris tsetse-fly trap.

This trap is in all essential respects a miniature Harris trap, except that black cloth is relied upon in place of hessian to attract the flies. The lack of a framework to support the cloth would appear superficially to be a drawback, especially in windy situations, but the tsetse-fly haunts are mostly very sheltered and the swaying which took place in a moderate breeze did not prevent the flies from entering. Tsetse-flies do not move about much in very windy weather, in any case.

It has been mentioned that the weather was humid and, on the basis of Harris' experience in Zululand, would be relatively unfavourable for trapping.* The daily catches were relatively low, even in the best catching weather experienced, the highest catch in a 24 hour period being made by the octagonal No. VIII model in a new site, namely, 101 flies (38 males, 63 females).

It is, of course, difficult to make accurate comparisons between the different models of traps tested, because the density of fly at different sites varies greatly and, in the case of *pallidipes*, is difficult to measure.

From 1st to 7th September the "Tin Top" caught 84 flies (42 males, 42 females), which was the highest catch of any trap in this period, including 3 Harris traps, three No. VIII and a miscellaneous selection of other traps. The next highest catch was 45 flies (17 males, 28 females) by a trap loosely draped with black cloth, which need not be described. The "Tin Top" on the other hand probably occupied the best site. In immediate competition with a Harris trap the "Tin Top" did not do so well, the catches being in the proportion of 3 : 1 in favour of the Harris model.

It is considered, however, that the last mentioned fact is probably of little significance. In general, if two otherwise efficient models are tested in immediate juxtaposition, it is the experience that the majority of the flies will go to the larger model. In one test of this nature, the "Tin Top" was moved early in the morning to a new site and the party then returned along the road to fetch a No. VIII model (black cloth) for a directly competitive test. Returning within about half an hour, it was observed that the " Tin Top " had already caught 7 flies and the prospects were that it would take a good catch during the day. The black mass of the No. VIII model was then erected a few feet away. Next morning it was found that the No. VIII had made the record catch of 101 flies mentioned above, and that not a single further fly had entered the " Tin Top." The mass of No. VIII had proved to be an overwhelming attraction. If the No. VIII had not been present, it can hardly be doubted that the " Tin Top " would have made an outstanding catch that day.

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* Incidentally the prevalent humidity may, it is feared, render trapping generally less effective along the eastern border of S. Rhodesia than it is in the drier climate of Zululand.

In point of fact, the No. VIII model, in direct competition with a Harris model in the same site, the traps being transposed occasionally, caught 206 flies (females = 55 per cent.) against 107 flies (females=72 per cent.) caught by the Harris model during the same period. The higher percentage of females in the Harris trap appears superficially to be an advantage, but the No. VIII actually caught the greater number of females, viz., 113 : 77. It is obvious that, presuming the sexes to be present in more or less equal numbers, no trap can continue to catch a large excess of females without failing to catch a considerable proportion of the males. Analysis of the flies caught explains how it comes about that the females are caught in excess in the traps, namely, through the failure of the traps to catch the fatter males.

If efficiency in catching in immediate competition with other types were to be regarded as the sole criterion, the choice would fall on the No. VIII model. This trap is, however, as cumbersome and expensive to construct as the Harris model and is less well adapted to withstand rain, besides being more liable to injury in transport.

Traps are, in any case, not intended to be used in direct competition with one another. The test of efficiency is not the ability of one model to attract flies away from another, but the ability of the particular model concerned to attract flies from their natural surroundings. The " Tin Top " certainly did the latter with reasonable efficiency.

On the basis of these short tests at one period of the year, it would be unjustified to claim that the new model is as efficient, trap for trap, as the Harris model, but the fact that it made a good showing under the humid conditions prevailing induces confidence that in drier weather it will give a still better performance.

With regard to the cost, a local firm quoted 5*s*. 9*d*. each for the metal catching cages, and has fulfilled a contract for 100 of these. The remainder of the construction is so simple that it can easily be carried out by supervised natives. The cost of the whole trap, including materials and native labour does not exceed 11*s*., that is, just under one-fifth of the lowest tender received for constructing the Harris model. It is judged that, whatever may be the respective individual efficiency of the two types, five of the smaller model are likely to prove considerably more useful than one of the larger model.

Summary.

1. *G. pallidipes* almost invariably attacks man on the leg from the knee downwards.
2. *G. brevipalpis* may attack man anywhere and not infrequently on the head.
3. Both species fill themselves readily with human blood once an attack has been made.
4. Neither sex of either species attacks man unless very hungry, as indicated by the very low mean fat content in the captures.
5. *G. brevipalpis* is apparently more reluctant even than *pallidipes* to attack man, and the fat contents in flies caught on man are proportionally lower than in the case of *pallidipes*.

6. Neither sex of *pallidipes* is attracted to a donkey unless hungry, *i.e.* ready to feed.

7. Male *brevipalpis* are apparently attracted to a donkey whether hungry or otherwise, but the females only when hungry. In this respect *brevipalpis* appears to resemble *morsitans*.

8. Both *brevipalpis* and *pallidipes* are very weakly attracted to a moving motor vehicle compared with *morsitans*.

9. It appears that males of both *brevipalpis* and *pallidipes* may be attracted to a moving motor vehicle when moderately fat, but the position in regard to the females is uncertain.

10. A grey blanket screen carried between two natives attracted *pallidipes* moderately and *brevipalpis* poorly.

11. *G. pallidipes* of either sex almost invariably settled on the bottom edge of the screen, whilst *brevipalpis* alighted anywhere on the side, and not infrequently on the top bar, level with the shoulders of the bearers.

12. The mean weight of fat in male *pallidipes* caught on the screen was rather lower than in the case of males caught on a donkey. In the case of the females, the mean weight of fat was the same in respect of both attractants.

13. Traps, more or less of the Harris type, but frequently with black cloth in place of hessian, caught a large number of *pallidipes* but very few *brevipalpis*.

14. Analysis of large numbers of trapped *pallidipes* revealed the fact that the mean fat content of the males was low, while the mean fat content of the females was much higher than in the case of females caught by means of any other attractant.

15. Of the trapped female *pallidipes* 14·5 per cent. were in advanced pregnancy, as against only 2·4 per cent. in the case of females of this species caught on a donkey.

16. The proportion of female *pallidipes* caught in the trap was 61·20 per cent. (2,430 flies).

17. In the case of the few *brevipalpis* caught in the traps the returns of fat also averaged high in the females and low in the males, but the numbers were too small for any reliable deductions.

18. It was judged from general observations that most *pallidipes* entered the traps between 4 p.m. and 5.30 p.m., dependent, however, upon the weather.

19. The most effective positions for the traps appeared to include those in which they received the rays of the sun in the later afternoon.

20. Further collections of *brevipalpis* males off the road in the late evening confirmed the fact that such males are mostly recently fed and fat.

21. Comparative tables are given showing the dry weight, weight of fat and stage of pregnancy in groups of *pallidipes* caught by means of different attractants.

22. It is probable that in the tables in the previous paper on *morsitans* many small 2nd stage larvae *in utero* were classed as 1st stage. The classification of 2nd and 3rd stage larvae in these tables refers to larvae 2 mm. or more in length, and the significance of the tables is not affected.

23. The figures given in Table XLIX in the paper on *morsitans*, which indicate a low proportion of 2nd and 3rd stage larvae in females caught on man, are of no significance as indicating reluctance of this sex to come to man. The last meal before larviposition appears normally to be taken when the larva is in the early 2nd stage.

24. The capture on a host of any considerable proportion of females containing advanced larvae does not indicate a thriving tsetse community, but betrays insufficient opportunity of feeding in the locality concerned.

25. Methods of estimating the state of hunger at the time of death in the case of dry tsetse flies are discussed.

26. Tables are given indicating the respective responses of *morsitans*, *pallidipes* and *brevipalpis* of both sexes to various attractants, and also, roughly, the proportion of the sexes in normal catches on these attractants.

27. It is remarked that no effective attractant for non-hungry *pallidipes* males has so far been found.

28. It is shown that there are certain consistent differences in the proportion between the mean weight of fat in the males and females respectively in catches of the different species on different attractants. If the female fat is expressed as percentage of the male fat the lowest figure refers to *morsitans* caught on man, whilst the highest refers to *pallidipes* caught in the traps.

29. Whilst in the case of both *morsitans* and *pallidipes* the traps tested have caught only lean (including young) males, but females in all stages of nourishment, young females seem to be inadequately represented in the catches of both species.

30. Figures obtained with *morsitans* indicate that the failure of the fat males and young females to be caught is due less to failure to be attracted to the outside of the traps than to failure to enter.

31. Under humid conditions relatively few lean *pallidipes* females of any age were caught in the traps, whereas under hot dry conditions old lean *morsitans* females were caught in considerable proportion. This is possibly due to the fact that in hot dry weather a low fat content is commonly associated with a reduced water content, but not necessarily in humid weather.

32. The figures indicating the alimentary condition of *pallidipes* caught in the traps are judged to support the view that hunger is not the primary stimulus leading to the attraction and capture of the flies.

33. In connection with the fact that only blood-sucking flies are caught in numbers in these traps, there are some indications that certain blood-sucking insects are more susceptible to heat than related vegetable feeders, but the question needs further investigation.

34. The fact that the traps catch flies only within a certain range of alimentary condition reduces their value as a barrier against fly movements.

35. The fact that well nourished heavily pregnant females are caught freely in traps erected in the open shows that such females must move about relatively freely.

36. A cheap form of tsetse trap is described, and some notes on trapping results are included.

Acknowledgments.

The collections of *pallidipes* and *brevipalpis* referred to in this paper were made by Mr. W. L. Williams, Entomologist, whose accurate notes have been relied upon to the full. The numerous dissections of these species have all been carried out by Mr. A. Cuthbertson, Entomologist, at Salisbury, and his careful work in this connection has resulted in a valuable contribution to the information obtained from the collections on different attractants.

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THE RELATIVE SIZE OF THE EYE AS A PHASE CHARACTER IN THE AFRICAN MIGRATORY LOCUST.

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In the course of biometric studies made on *Locusta migratoria migratorioides* (R. & F.) it was found that the compound eyes of *solitaria* adults appeared relatively larger than those of *gregaria*, and measurements were made to test this. The material used was from West Africa, chiefly from Nigeria and the Gold Coast.

Measurements of the eye were made with a screw micrometer eye-piece fitted to a binocular microscope. The vertical diameter, or height (D) and horizontal diameter (d) were found by moving the locust until the maximum measurement of the eye in each direction was obtained. The other measurements were made with a pair of dividers and a millimetre scale.

To find whether the height of the eye could be taken as an indication of its true size in each phase, it was necessary to find whether the shape remained constant. The height and horizontal diameter of the eyes of five males and five females of each phase were measured, and the ratio D/d calculated. This ratio was found to vary only from 1·39 in both sexes of the phase *gregaria* to 1·40 in the females of *solitaria*, proving that the shape does not differ in solitary and gregarious locusts and the height alone can therefore be used as an indication of size.

The height of the eye was measured for ten males and twenty females of each phase. To find the size of the eye relative to the size of the body, the height D was compared to the length of elytra (E). The height of eye was also compared to the width of the head (C). These values, together with the ratio of elytra to hind femur (F) as an indication of the degree of solitariness and gregariousness of the specimens examined, are given in Table I.

TABLE I.

	♂♂		♀♀	
	Greg.	Sol.	Greg.	Sol.
E(cm.) ...	4·88±·059	4·00±·043	5·12±·040	5·16±·047
D(cm.)	0·319±·0045	0·307±·0044	·321±·0031	·355±·0033
E/F	2·051±·0089	1·814±·0166	2·144±·0188	1·830±·0129
E/D	15·27±·165	12·88±·184	15·97±·152	14·57±·122
C/D ...	2·498±·0321	2·032±·0273	2·631±·0268	2·367±·0170

The absolute size of the eye in females is greater in solitary than in gregarious forms, but in males it is less in the solitary than in the gregarious. The E/D ratio shows a considerable difference in the two phases, being greater in the gregarious than in the solitary phase in both sexes. This difference is shown in fig. 1. The difference is more marked in the males, where the means of the E/D value for the two phases differ by 2·39, than in the females, where the difference is only 1·40. Both these differences are significant, however, that in the males being 9·7 times and in the females 7·2 times the standard error of the mean.

It might be expected that the relative size of the eye would be somewhat greater in *solitaria* males than in *gregaria* males on account of the much smaller absolute size of the former, the difference in length of elytra being 0·92 cm. No such consideration can explain the difference in E/D between gregarious and solitary females, however, where the difference in E is only 0·04 cm.

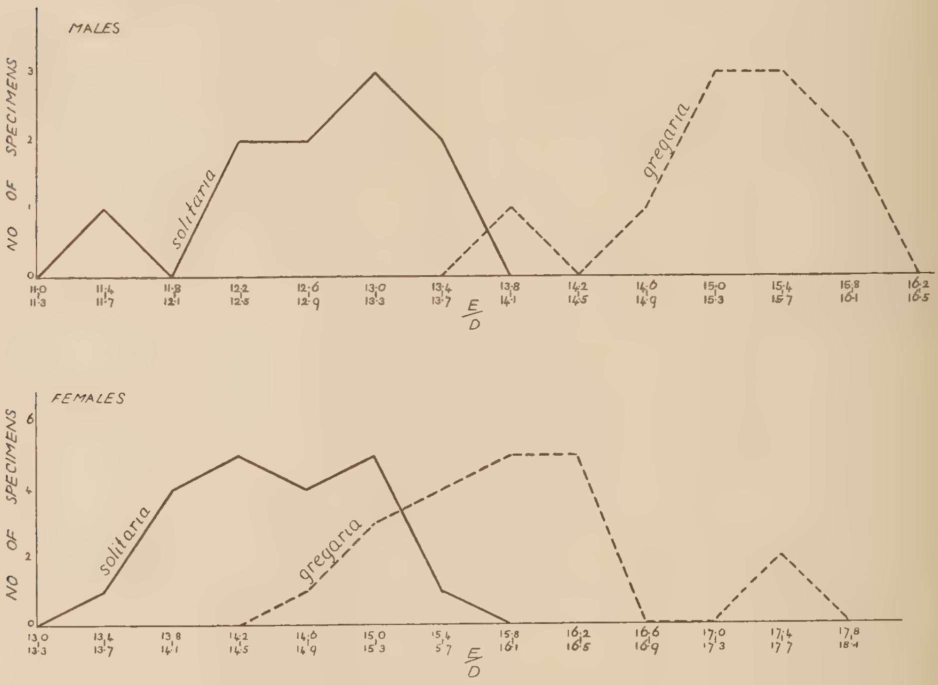

Fig. 1. Curves showing distribution of the ratio E/D in solitary and gregarious males and females.

The decrease in the relative size of the eye in gregarious locusts is not due to a decrease in the size of the head, since the ratio C/D in the gregarious phase shows an increase over that of the solitary phase similar to that for the E/D ratio. The difference in relative size of the eye, therefore, appears to be a distinct phase character of *Locusta migratoria migratorioides*, the eye being relatively larger in the *solitaria* than in the *gregaria* phase.

An attempt was made to find whether the facets differed in size in the two phases. The average width of a facet for several regions as near to the centre of the eye as possible was found for several solitary and gregarious males. It was not possible, however, to show any difference in this respect between the two phases, since the variation in width from slightly different regions in the same eye was considerable. This variation was to be expected from Bernard's (1937) work on *Schistocerca gregaria* (Forsk.) in which he showed that the facets were of different size in successive zones of growth.

In view of the suggestion of Kennedy (1939) that gregarious instinct is " a form of ' visual compensation ' reaction well developed in gregarious individuals in relation to their fellows, and apparent in crude form in solitaries," it might have been expected that the eyes would be relatively larger in gregarious than in solitary individuals. As has been shown above, however, the reverse is true for *Locusta migratoria* *migratorioides*. If Kennedy's suggestion is correct, this would mean that the visual compensation reaction probably does not increase with the size of the eye.

I am very grateful to Dr. Uvarov, who suggested the work, for his help and advice.

Summary.

The relative size of the compound eye constitutes a good phase character in *Locusta migratoria migratorioides*, the ratio E/D (length of elytra to the maximum vertical diameter of eye) being over 15 in the males and about 16 in females of the gregarious phase, as against about 13 in the males and about 14·5 in the females of the solitary phase.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st July and 30th September, 1940 :—

BOMBAY NATURAL HISTORY SOCIETY :—485 Orthoptera ; from India.

Mr. H. E. BOX :—52 Lepidoptera ; from the Gold Coast.

CHIEF CONSERVATOR OF FORESTS, NIGERIA :—260 Isoptera.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—427 Coleoptera and 637 Orthoptera ; from East Africa.

Mr. G. S. COTTERELL, Government Entomologist :—3 *Cordylobia*, 3 other Diptera, 11 Coleoptera, 170 Formicidae, 1 species of Coccidae, 7 other Rhynchota, 40 Psocidae, 4 Orthoptera, and 5 Millipedes ; from the Gold Coast.

Mr. D. VESEY FITZGERALD :—3 Cecidomyiidae ; from the Seychelles : and 80 Parasitic Hymenoptera ; from Malaya.

Mr. J. L. FROGGATT, Government Entomologist :—8 Diptera, 184 Coleoptera, 34 Parasitic Hymenoptera, 100 other Hymenoptera, and 110 Rhynchota ; from New Guinea.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—3 Diptera, 24 Coleoptera and 11 larvae, 2 Parasitic Hymenoptera, 30 Lepidoptera, 1 species of Aphidae, 1 species of Aleurodidae, 200 other Rhynchota, and 2 Trichoptera ; from the Punjab, India.

Mr. A. L. HILLS :—1 Lepidopterous larva ; from England.

Mr. G. H. E. HOPKINS, Medical Entomologist :—113 Diptera ; from Uganda.

INDIAN MUSEUM, CALCUTTA :—1,248 Orthoptera ; from India.

Mr. R. A. LEVER, Government Entomologist :—200 Diptera, 30 Coleoptera and 10 larvae, 22 Parasitic Hymenoptera and 30 cocoons, 5 Lepidoptera, 1 species of Coccidae, 3 species of Aleurodidae, 50 Cimicidae, 40 other Rhynchota, 2 Psocidae, 5 Orthoptera, 5 Scorpions, and 2 Centipedes ; from the Fiji Islands.

Mr. H. M. MORRIS, Government Entomologist :—1 species of Coccidae ; from Cyprus.

Mr. F. B. NOTLEY, Entomologist :—24 Parasitic Hymenoptera ; from Tanganyika Territory.

Mr. H. T. PAGDEN, Entomologist :—4 tubes of Nematoda ; from Malaya.

Mr. E. F. Peck, Veterinary and Agricultural Officer :—1 *Pangonius* and 20 Thysanura ; from British Somaliland.

Mr. A. S. TALHOUK :—16 Coleoptera ; from Syria.

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